OBSERVATIONS DURING HIGH GRADIENT LINAC TESTING WITH A 4X POWER AMPLIFYING DUAL RESONANT RING SYSTEM

Haimson Research Corporation

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Grant No.DE-FG02-05ER84362

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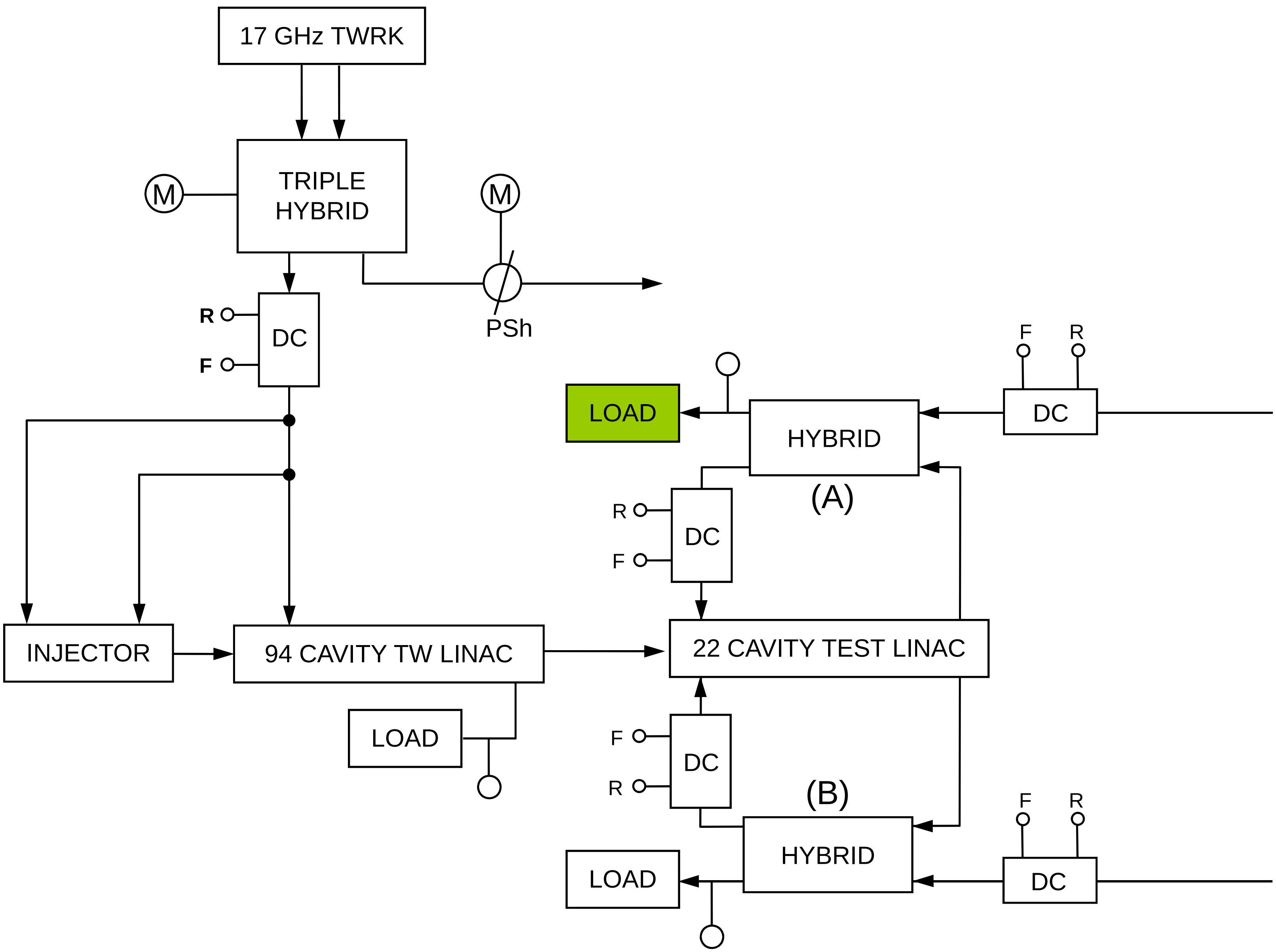
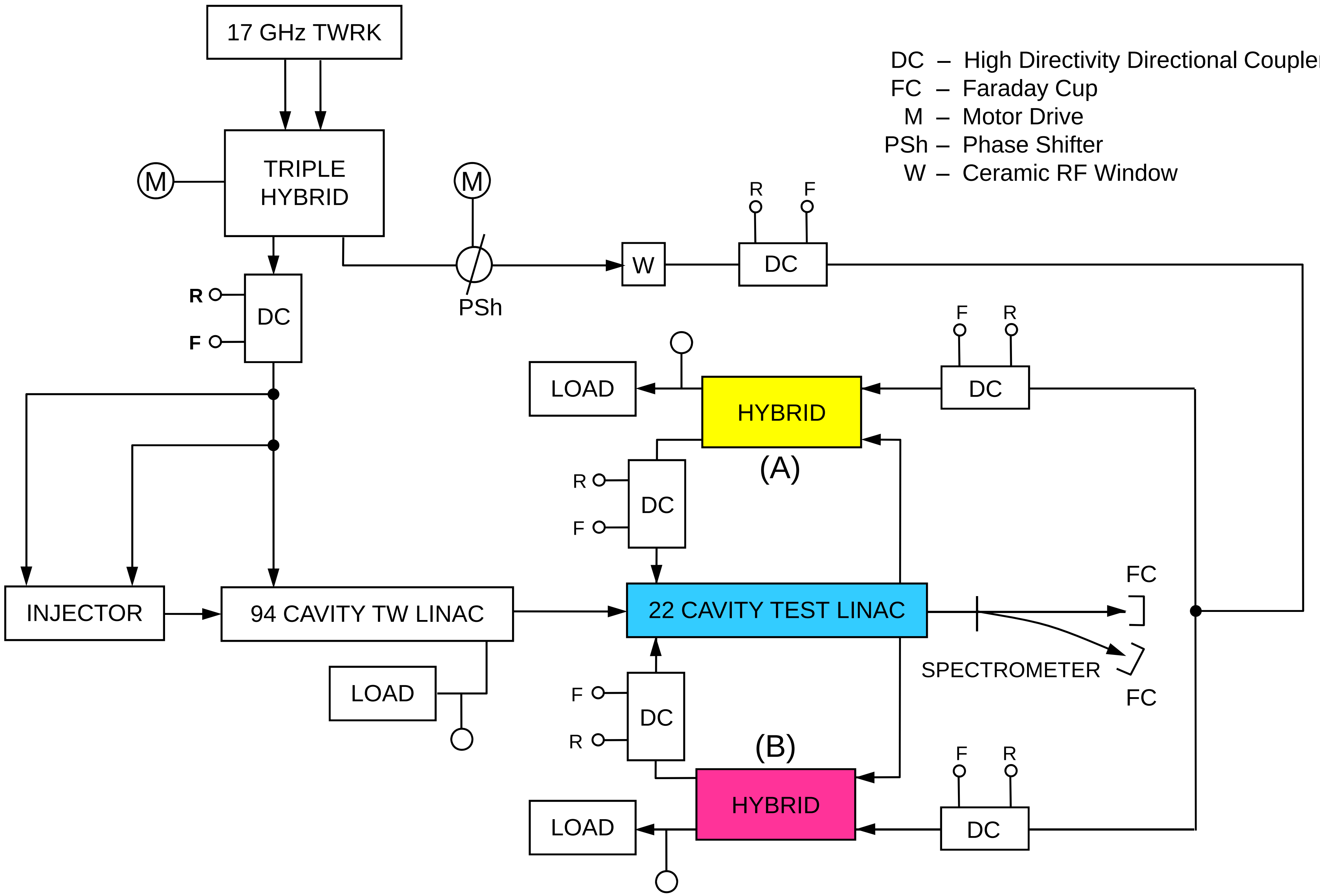
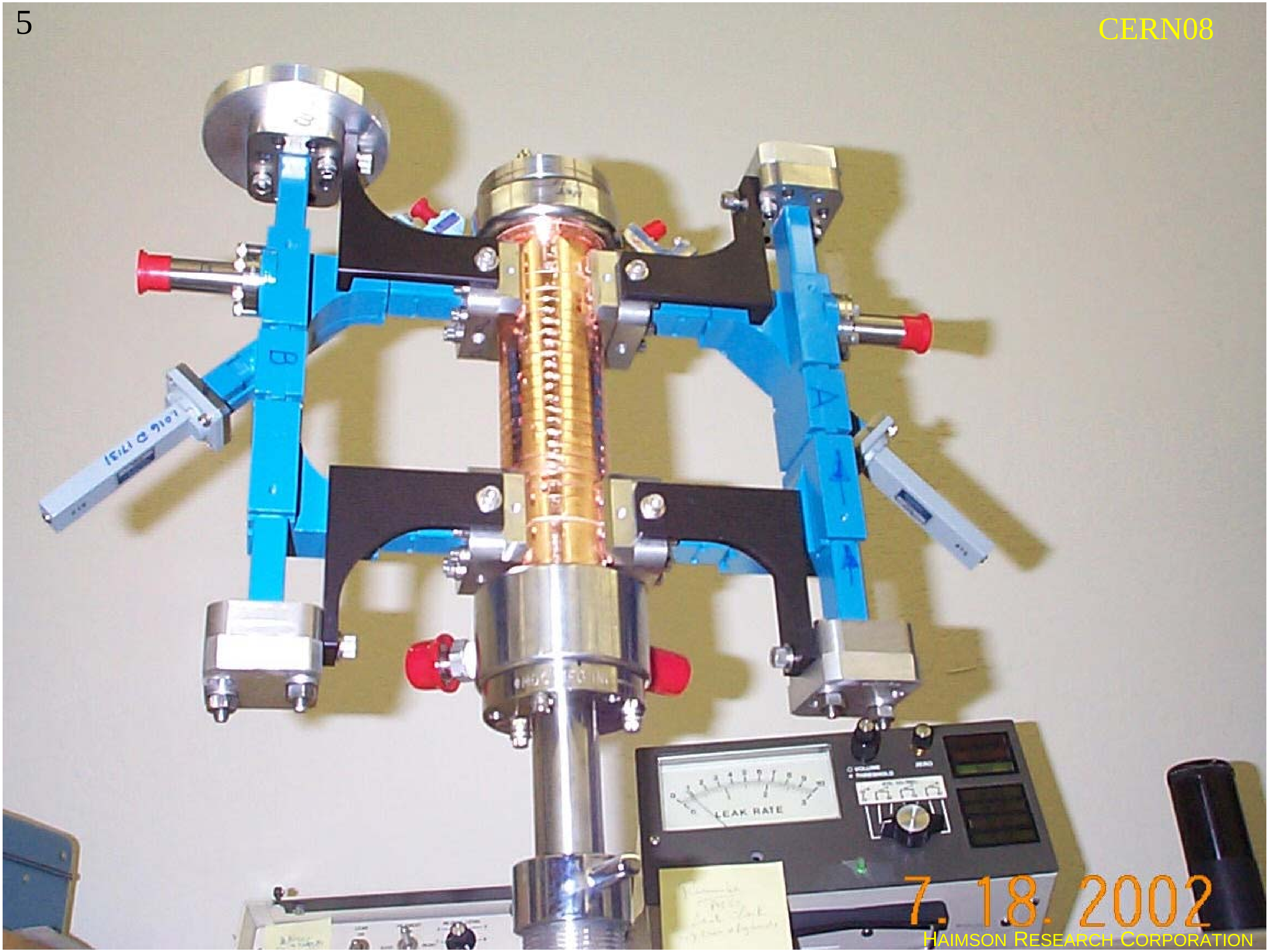

17 GHz TWRK
TRIPLE HYBRID
M
M
DC
R
F
PSh
INJECTOR
94 CAVITY TW LINAC
LOAD
LOAD
HYBRID
(A)
DC
R
F
F
R
DC
22 CAVITY TEST LINAC
F
R
DC
(B)
HYBRID
LOAD
F
R
DC


17 GHz TWRK
TRIPLE HYBRID
M
M
DC
R
F
PSh
W
DC
R
F
DC – High Directivity Directional Coupler
FC – Faraday Cup
M – Motor Drive
PSh – Phase Shifter
W – Ceramic RF Window
F
R
DC
LOAD
HYBRID
(A)
R
F
DC
INJECTOR
94 CAVITY TW LINAC
22 CAVITY TEST LINAC
FC
SPECTROMETER
FC
LOAD
F
R
DC
(B)
HYBRID
LOAD
F
R
DC


CERN08
B
A
LEAK RATE
7. 18. 2002
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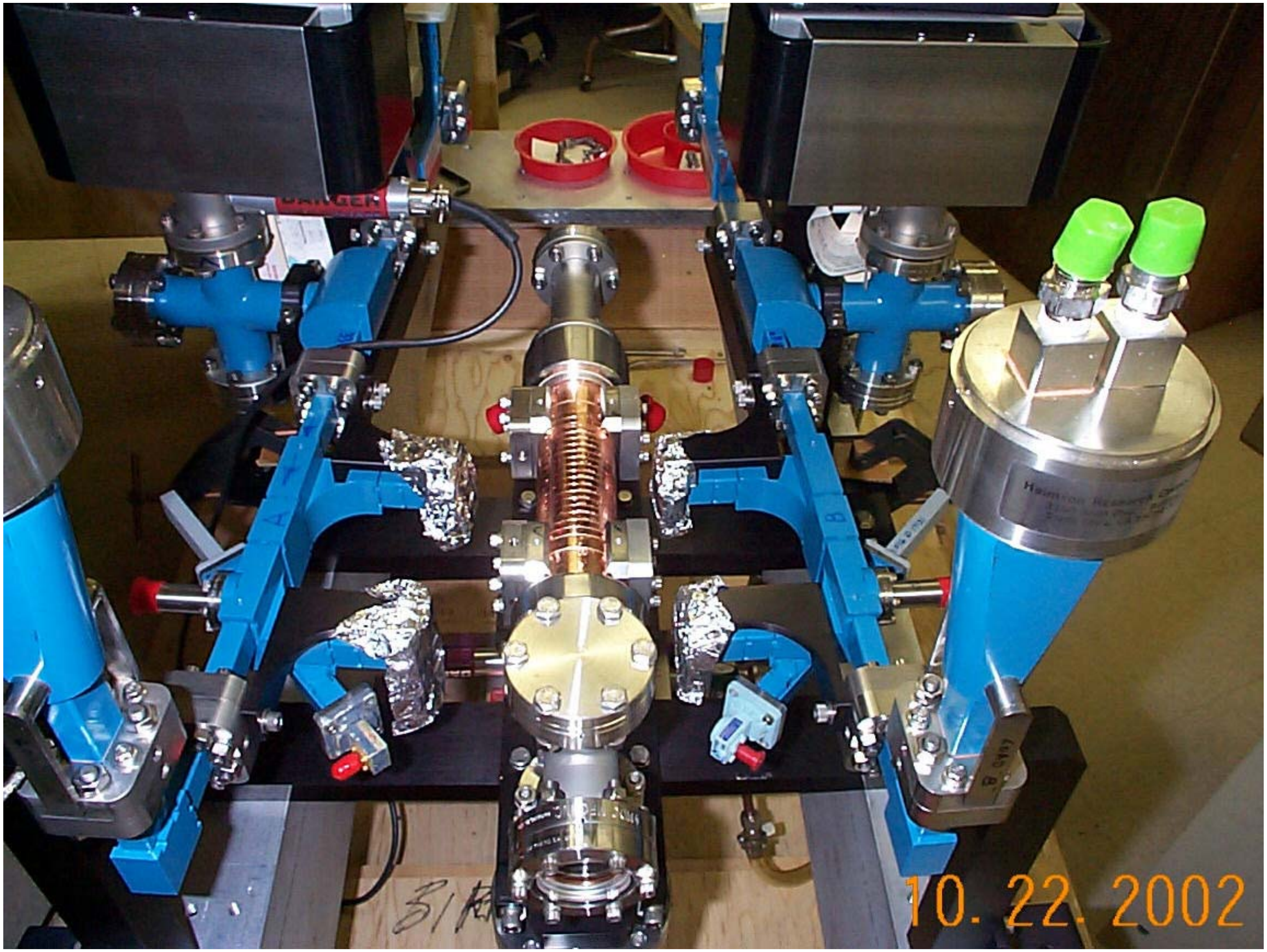
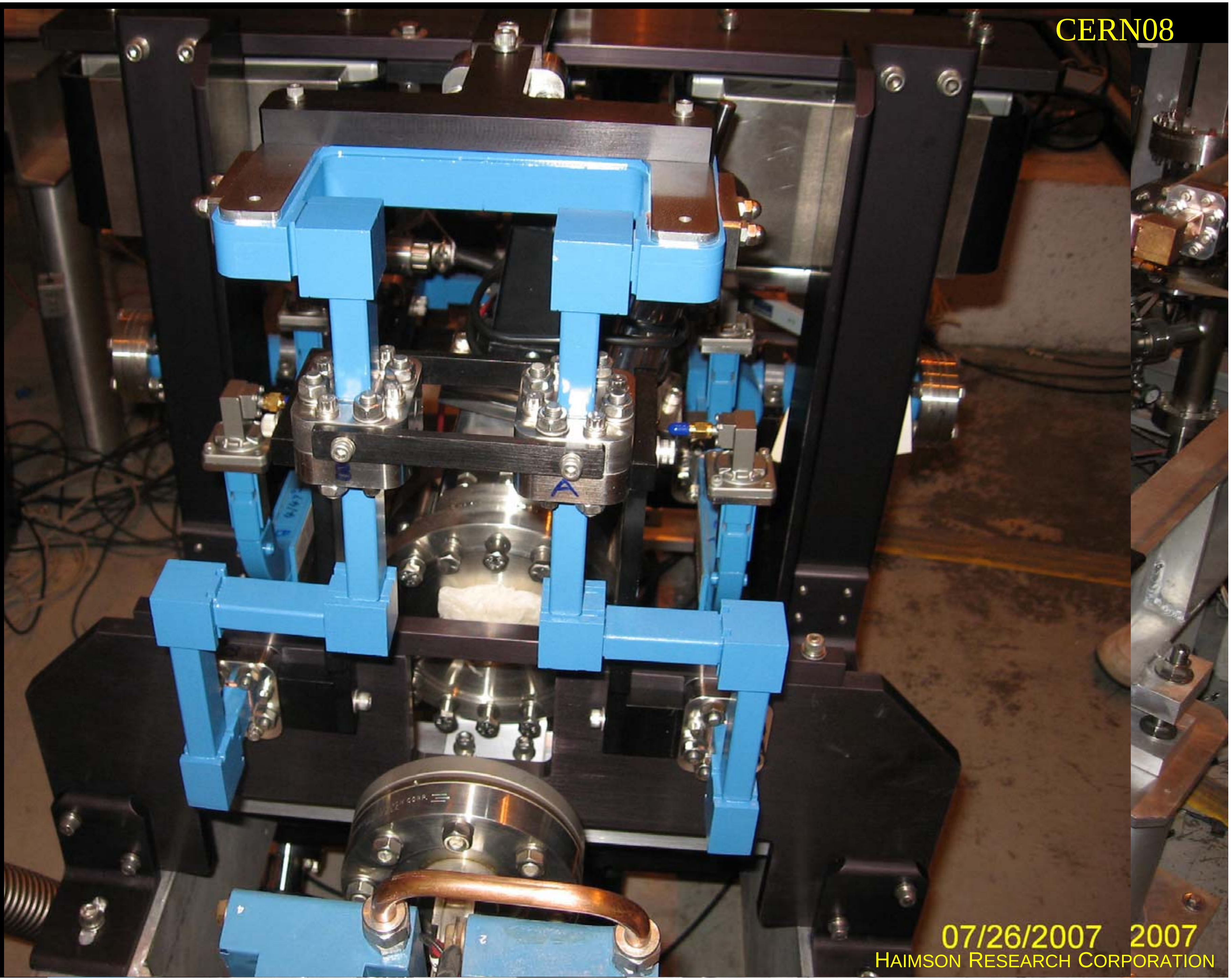


View of All-Copper 17 GHz Linac Structure and 4X Peak Power Amplifier System.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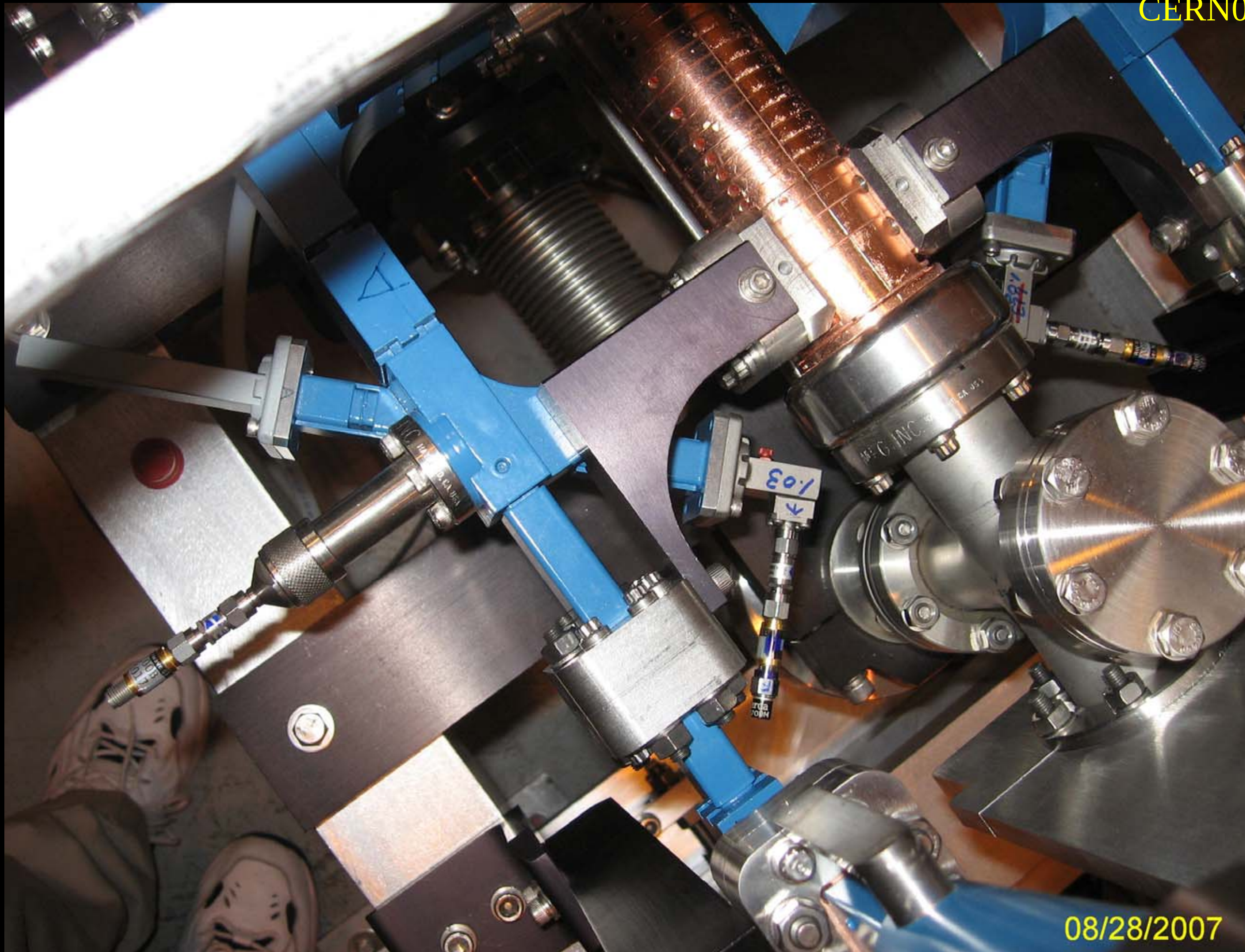

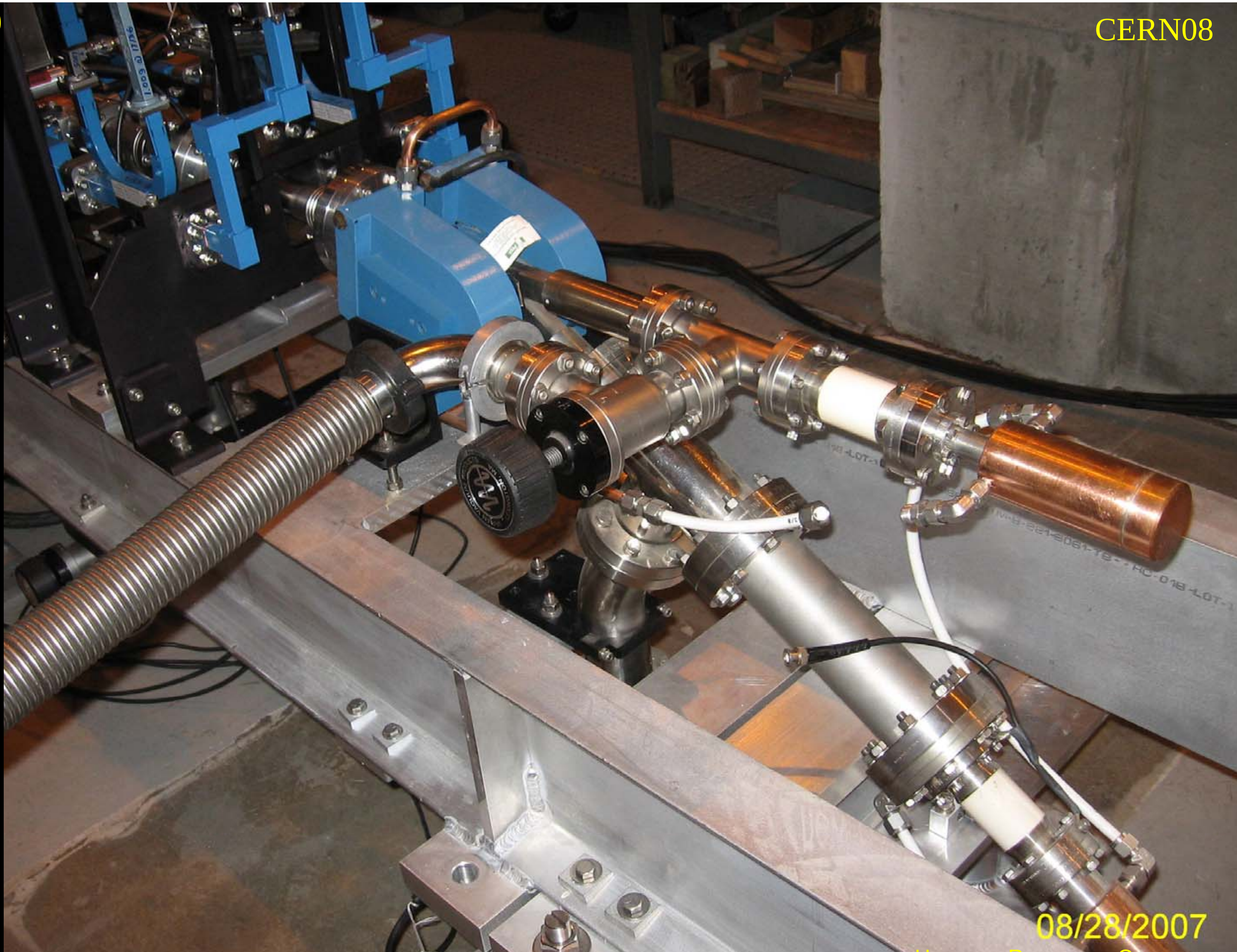
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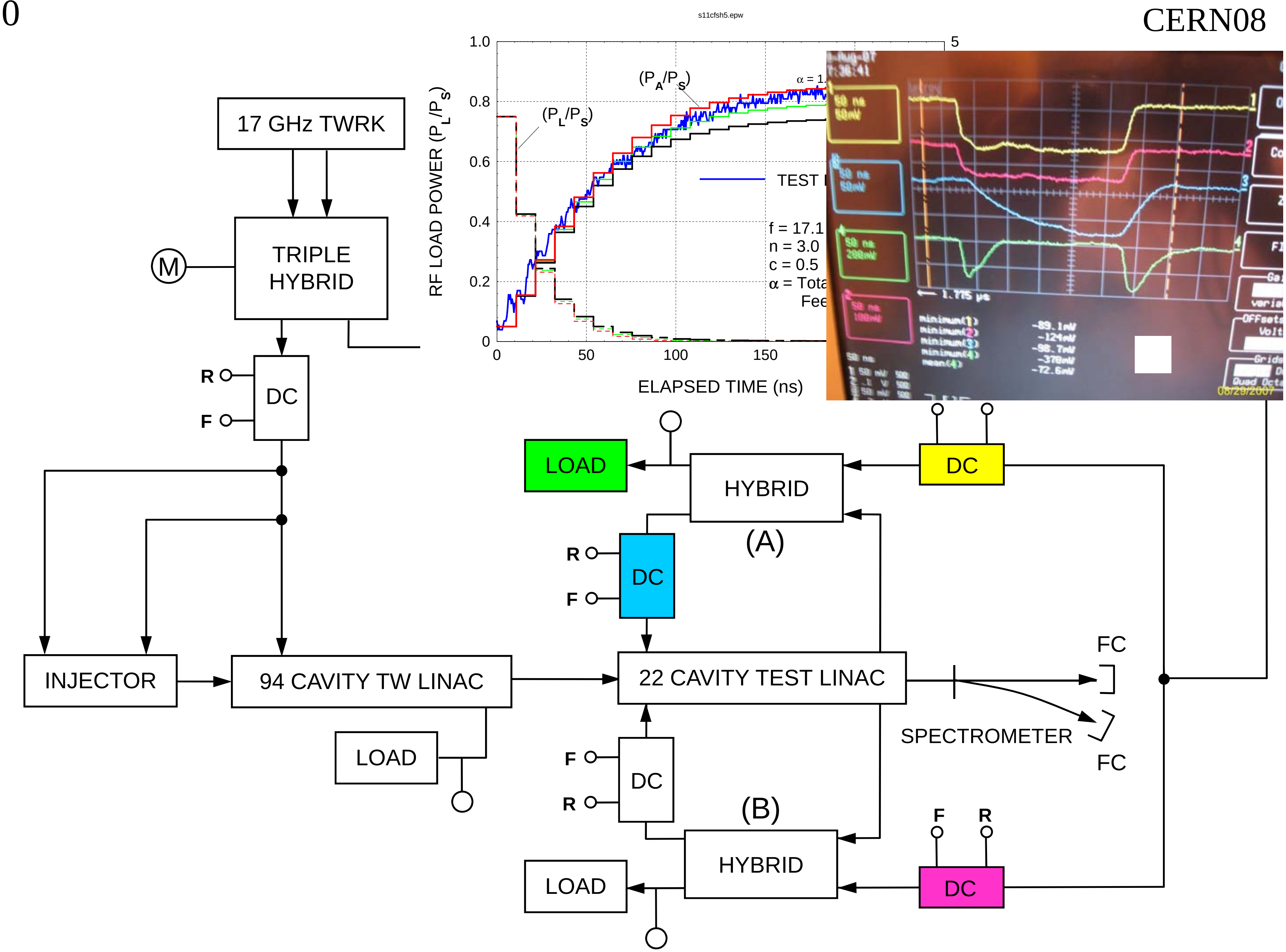

s11cfsh5.epw
RF LOAD POWER (P_L/P_S)
ELAPSED TIME (ns)
(P_A/P_S)
(P_L/P_S)
α = 1.
TEST
f = 17.1
n = 3.0
c = 0.5
α = Tota
Fee
1.0
0.8
0.6
0.4
0.2
0
0
50
100
150
5
17 GHz TWRK
TRIPLE HYBRID
M
DC
R
F
INJECTOR
94 CAVITY TW LINAC
LOAD
LOAD
HYBRID
(A)
DC
DC
22 CAVITY TEST LINAC
FC
SPECTROMETER
FC
DC
(B)
HYBRID
LOAD
DC
08/29/2007

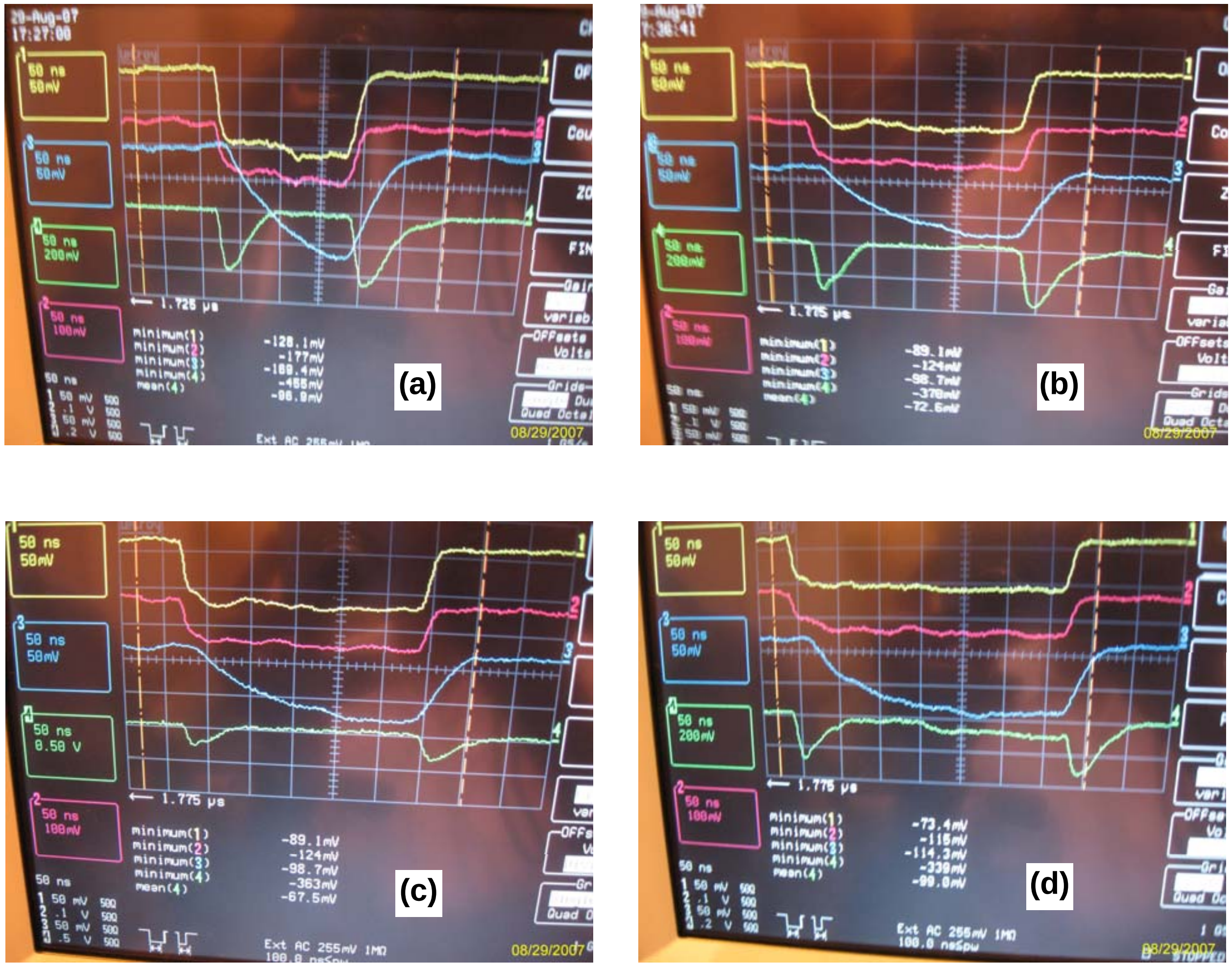
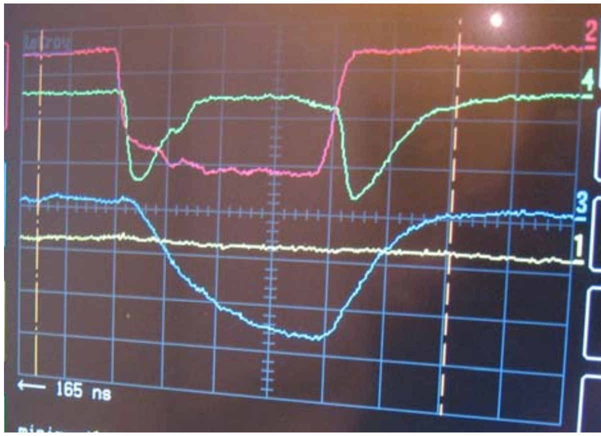


Figure 2. (a) through (d) Time Base = 50 ns/div, showing Bridge Input Power in Arms A (yellow) and B (red), Linac Input Power in Arm A (blue) and Bridge Load Power in Arm A (green).

NORMAL LINAC OPERATION

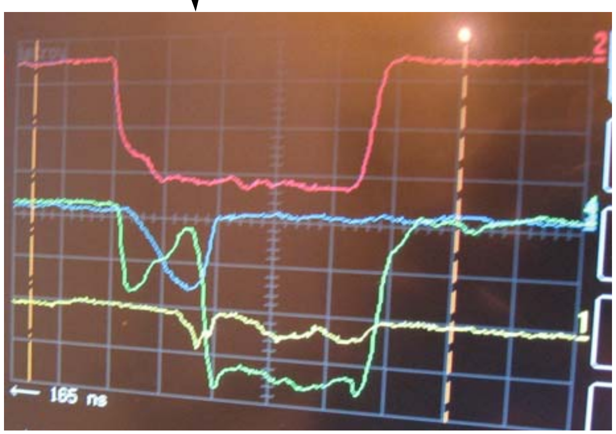


RF Source Power
Bridge Load Power
Linac Input Power
Linac Reflected Power

High Power RF Waveforms of the Bridge Protected High Gradient 17 GHz Linac

Frequency = 17137 MHz. Time Base = 50 ns/div.

WITH ARC IN LINAC



Showing that when an Arc Occurs in the Linac, the Linac Input Power (blue) is Rapidly Truncated and, for the Remaining Portion of the Klystron RF Pulse the Bridge Input Power (red) is Automatically Directed into the Bridge Load (green). Thus, the Linac Power Amplifying Bridge Assists in Automatically Protecting both the RF Source and the High Gradient Linac Structure.

"A Linear Accelerator Power Amplification System for High Gradient Structure Research," in *Advanced Accelerator Concepts*, AIP Conf. Proc., No. 472, pp. 1003–1013, 1998.

Observations During High Gradient Testing of the All-Copper 22 Cavity Linac

- At a prf of 2 Hz, each 10 ns widening of the RF pulse (from 100 to 200 ns) took 2×10^{3} pulses to clean up.
- After 4 hours of operation, the linac system processed up to 60 MV/m using pulse widths of 180 ns.
- Gradient data confirmed with beam energy measurements.
- A notable difference in the linac structure processing behavior was the complete absence of retrogressive thresholds even after breakdown discharges with wide RF pulses.
- After 30 accumulated hours of processing, a gradient of 73-74 MV/m was achieved at a linac input power of 32 MW.

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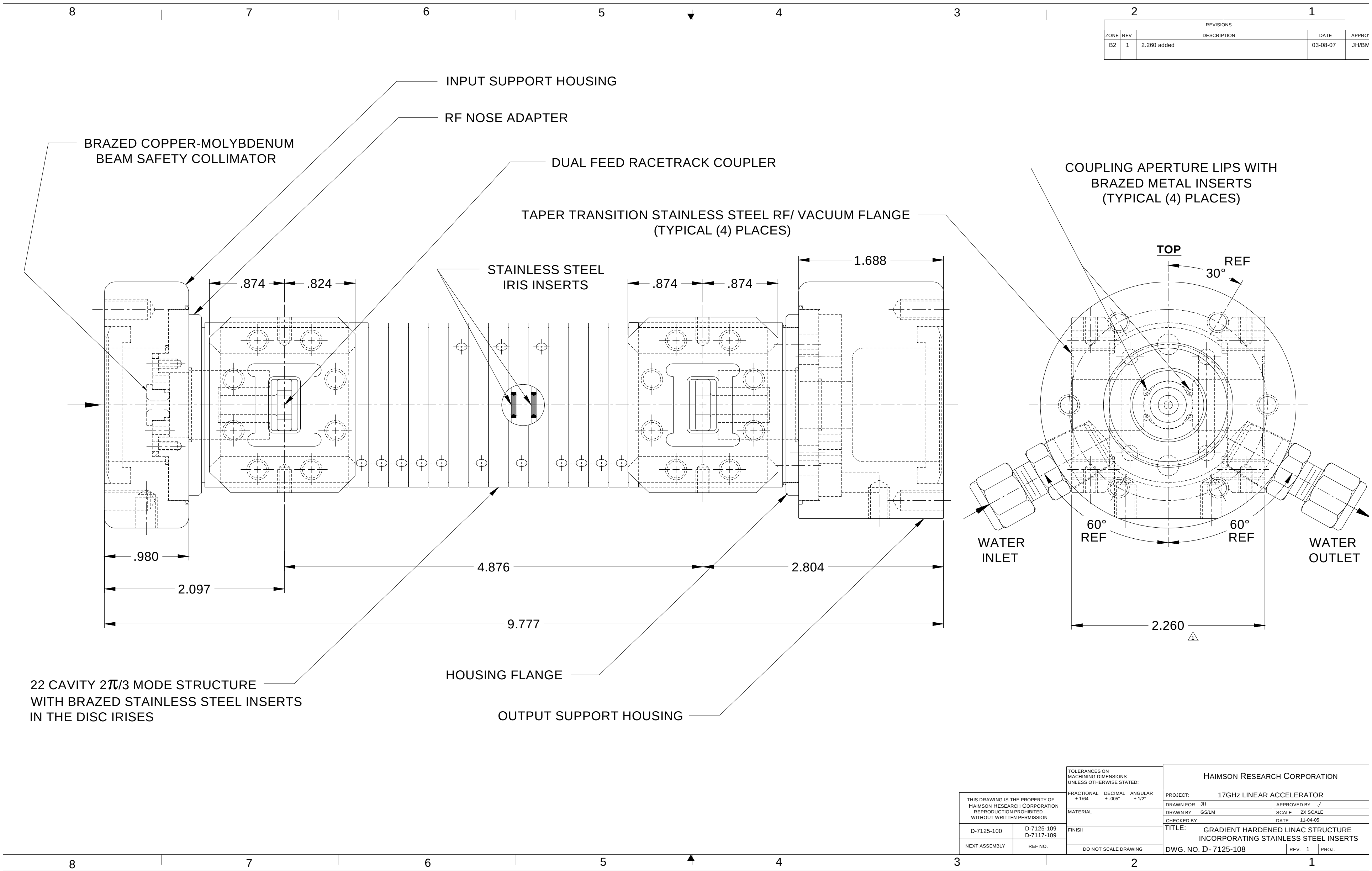

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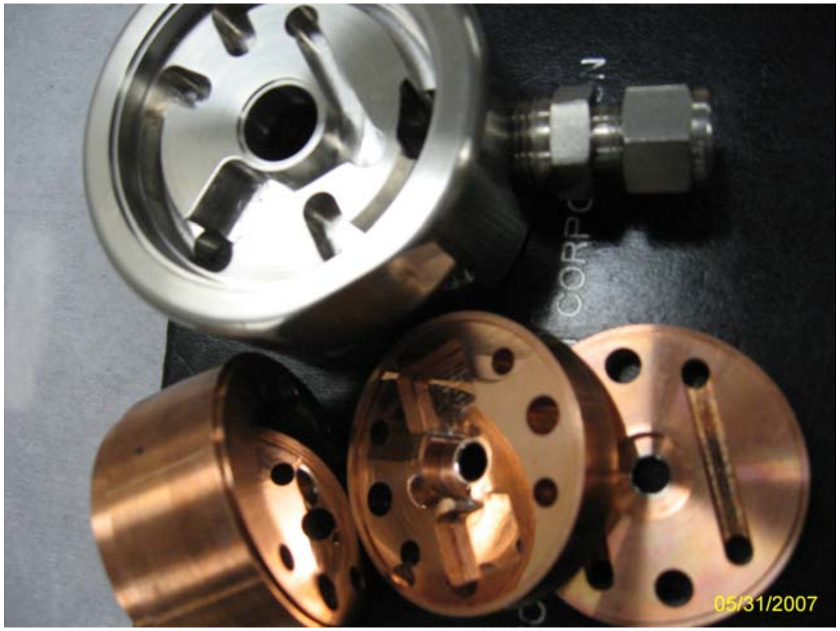
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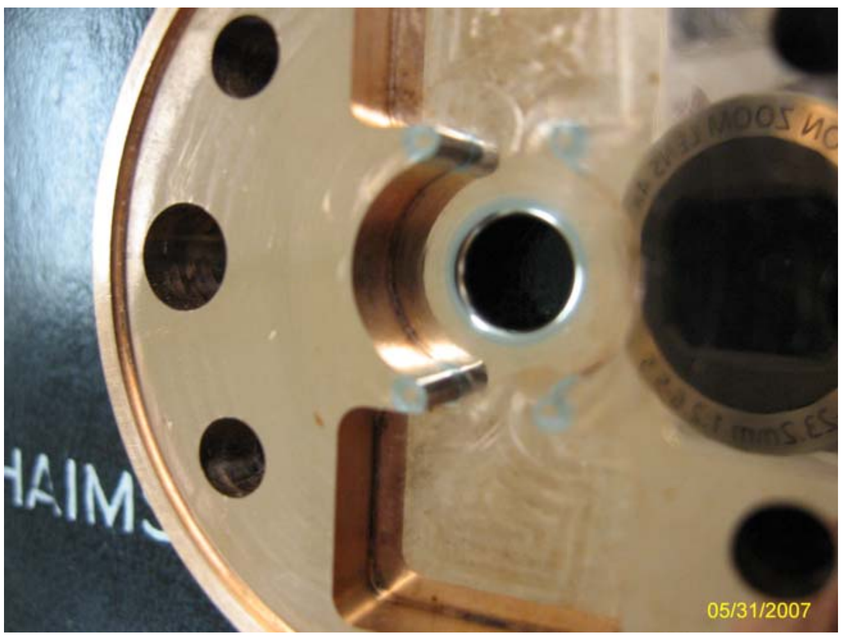
05/31/2007


TOP
"A" TYPE COPPER/SST CELL
(C-7125-117 R1)
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GRADIENT HARDENED 17GHz LINAC
PROJECT:
DRAWN FOR JH
APPROVED BY
SCALE 2X SIZE

FINAL DESIGN AND OPERATING PARAMETERS OF THE 17 GHz SST/CU LINAC STRUCTURE AND FEEDBACK LOOP COMPONENTS

Frequency . . . . 17.136 GHz

Linac Structure Beam Aperture ϕ . . . . 0.5999 cm

Number of Cavities ($2\pi/3$ Mode). . . . 22

Cavity Phase Velocity . . . . 4 at c, 2 at 1.005c, 2 at 1.010c, and 14 at 1.015c

Linac Structure Attenuation Parameter. . 0.178 Np

RF Bridge Coupling Coefficient

$[C=(n+1^{)-1/2}]$ 0.5

Voltage Transmission Coefficient

$\{TC = [n/(n+1)]^{1/2}\}$ 0.84

Input Power from RF Source	10	(15)	MW
Linac Steady State Input Power. .	33	(49.5)	MW
Maximum Accelerating Gradient. .	67	(82)	MV/m
Maximum Surface Gradient	150	(184)	MV/m

SOME OBSERVATIONS DURING HIGH GRADIENT LINAC TESTING WITH A 4X POWER AMPLIFYING DUAL RESONANT RING SYSTEM

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Acknowledgements ⟶

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[redacted]

STRENGTH OF MATERIAL PARAMETER COMPARISON OF OFHC COPPER, 304 STAINLESS STEEL AND MOLYBDENUM

Parameter	OFHC Copper	Type 304 Stainless Steel	Molybdenum
Tensile Strength (psi)	28000*	79000	90000
Yield Strength (psi)	2000	35000	56000
Modulus of Elasticity (psi)	16×10^6	29×10^6	50×10^6
Maximum Elongation (%)	60	54	15
Melting Temp. (°C)	1083	1454 – 1499	2622
Temp for 10^{-5} mm Vapor Pressure (°C)	942	1105	1987
Lattice	f-cc**	f-cc	b-cc†

* At room temperature
** Face-centered cubic
† Body-centered cubic

COMPARISON OF OFHC ANNEALED COPPER, LOW CARBON 304 STAINLESS STEEL AND MOLYBDENUM SURFACE RESISTIVITY AND SKIN DEPTH AT 17.136 GHz

Material	Bulk Resistivity at 20°C ρ (Ohm–m)	Surface Resistivity at 17.136 GHz R_s (Ohm)	Skin Depth at 17.136 GHz δ (μm/μ'')
Annealed OFHC Copper	1.724×10^{-8}	0.034	0.505 μm (20 μ'')
304L Stainless Steel	6.4×10^{-7}	0.208	3.07 μm (121 μ'')
Molybdenum	5.7×10^{-8}	0.062	0.918 μm (36 μ'')

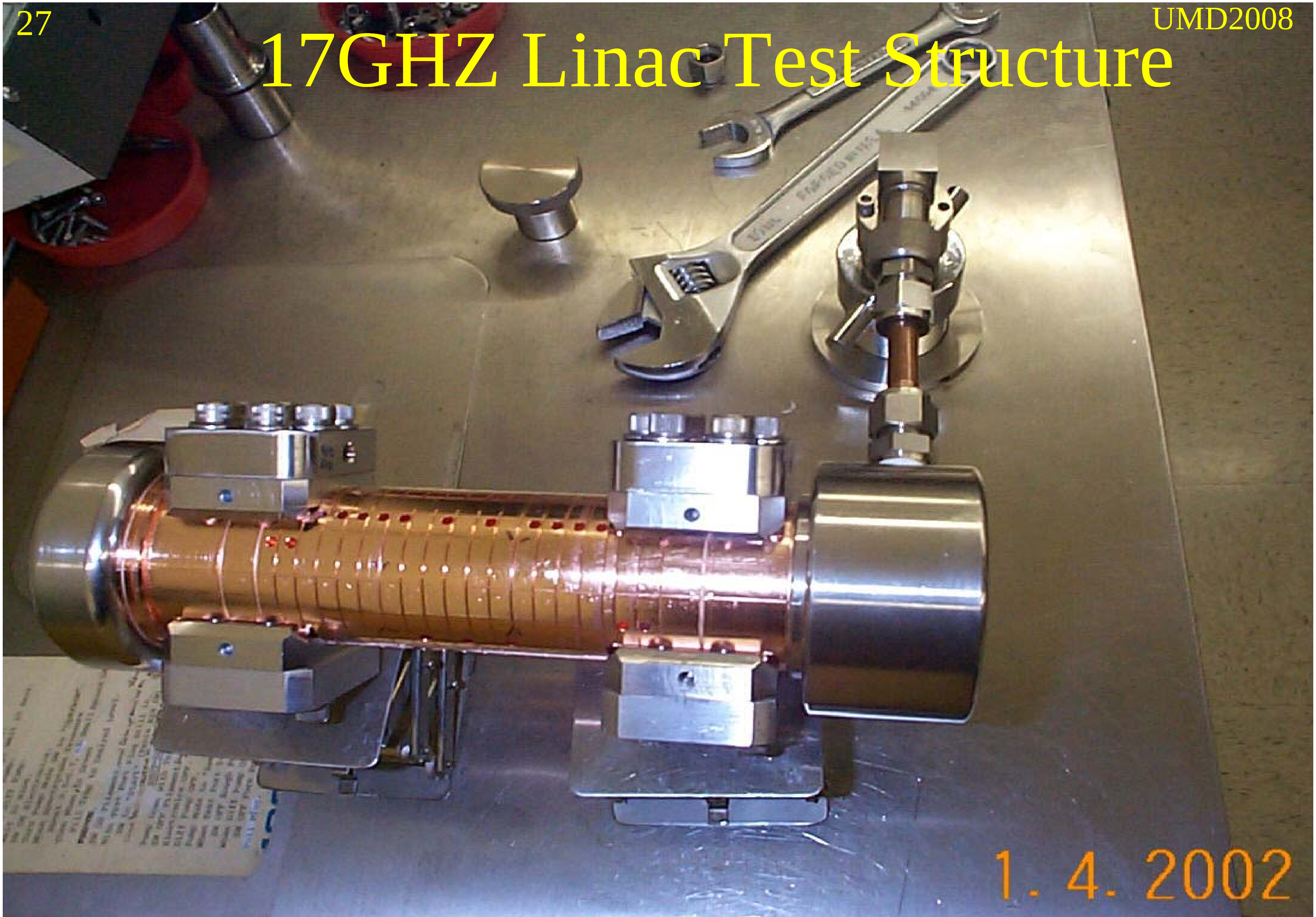
Linac Structure Harmonic Mean Group Velocity $(v_g)_{hm}$	0.039 c
Total Loss in Each Feedback Loop	1.25 dB
Feedback Loop Transit Time $(T_F + T_{RWG})$. .	11.8 ns
RF Bridge Ratio (n)	3
RF Power Build-up Ratio (n+1)	4

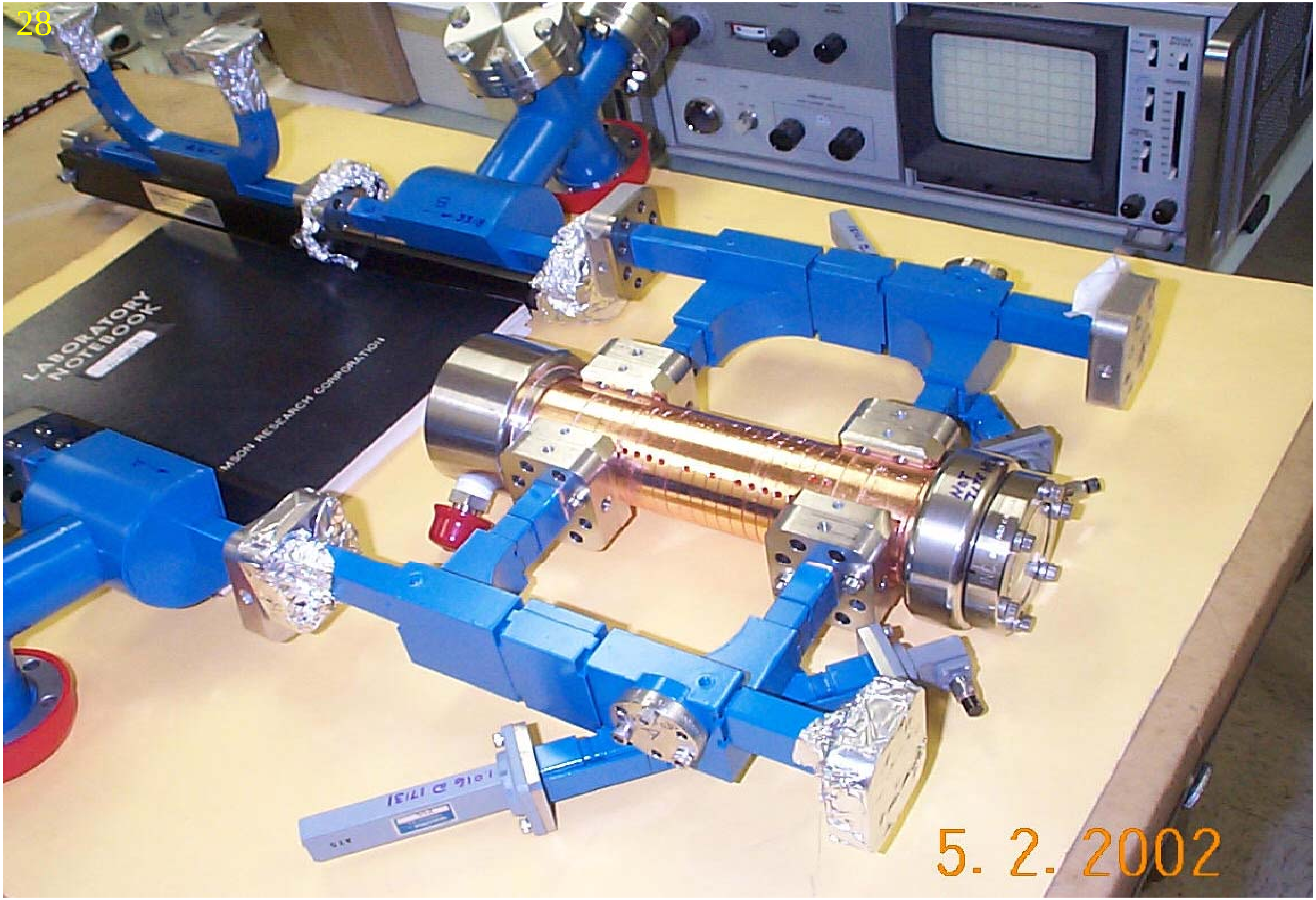
Time to Attain 99.5% Steady State			
RF Power Buildup	236	236	ns
Steady State Beam Loading			
Derivative	0.67	0.67	MeV/A
Output Phase/Frequency Sensitivity			
of Linac Structure ($\partial\theta/\partial f$) . . .	3.9	3.9	deg/MHz
Output Phase/Temperature Sensitivity			
of Linac Structure ($\partial\theta/\partial T$) . . .	1.1	1.1	deg/°C

LINAC AND RF BRIDGE DESIGN PARAMETERS

Feedback Loop Loss	1.25 dB
Feedback Loop Transit Time	11.8 ns *
Total Phase Length of Feedback Loop	8280 +/- 2 deg. *
Loop Phase Dispersion	4.3 deg/MHz
Loop Length Sensitivity	58.4 micron/deg.

17GHZ Linac Test Structure

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NOTEBOOK
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