Development of a High Power Test System for New Power Grid Tubes for 200 MHz

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Outline

- **Planned Upgrade to LANSCE DTL RF Plant**
- **New Power Amplifiers, FPA and IPA**
- **Development of Test Facility for Amplifiers**
  - **Reuse of LEDA Facility**
  - **Anode High Voltage Power**
  - **Filament, Screen and Control Grid Power**
  - **Solid State Driver Stage**
  - **RF Water Load**
  - **Circulator Test**

LANSCE Drift Tube Linac

First 60 meters of the 760 meter LANSCE linac

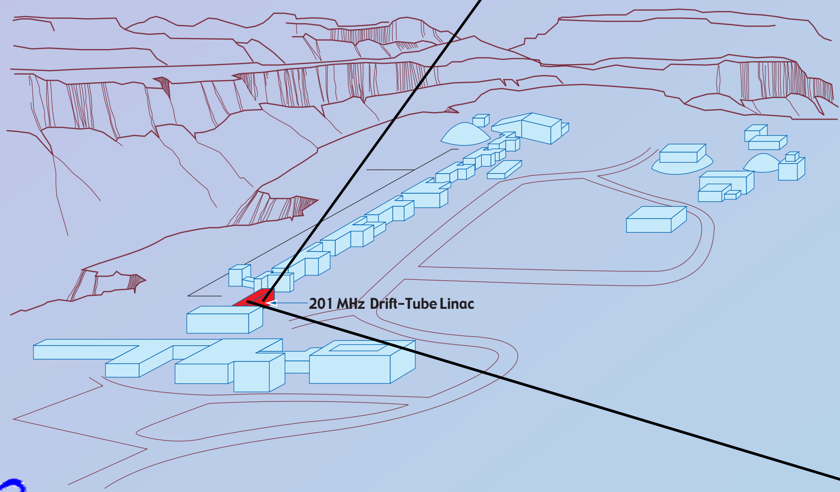
4 Post Coupler-Stabilized Alvarez tanks

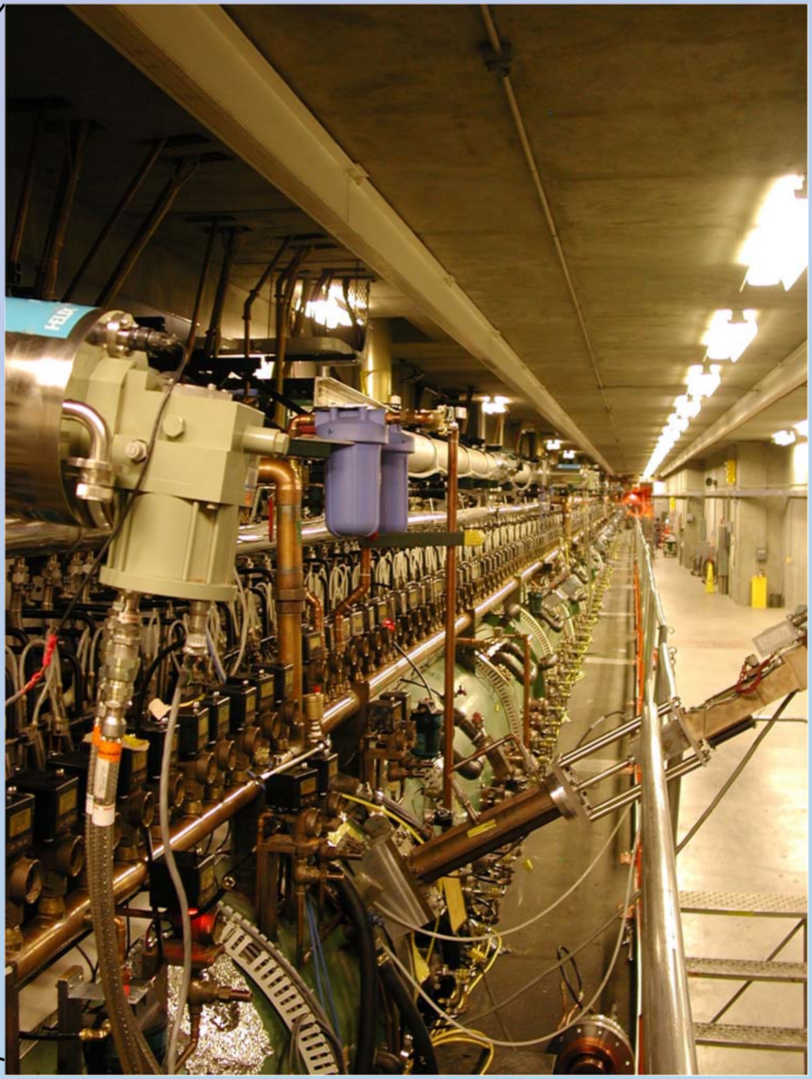
Designed and installed in 1967-1968

H^+ and H^- Protons accelerated from 0.75 to 100 MeV

Beam Transferred to room temp CCL at β= 0.428

DTL receives 201.25 MHz pulsed RF power through 35.5 cm coaxial transmission lines from 4 RF system





DTL RF Power Limitations

- DTL formerly accelerated 17 mA peak H^+ (LAMPF)
- Presently operating about 11-13 mA of H^+ and H^-
- RF duty factor as high as 12% to handle all beams
- Final power amplifier triode (7835) sometimes operating at 90% of its “safe” anode dissipation limit
  - Impossible to operate with higher peak current with such average power, especially for the second DTL tank (longest)
  - RF system is unable to provide adequate power for future LANSCE programs, without significant engineering improvements
- Replacement system being developed, tested, for installation 2011-15

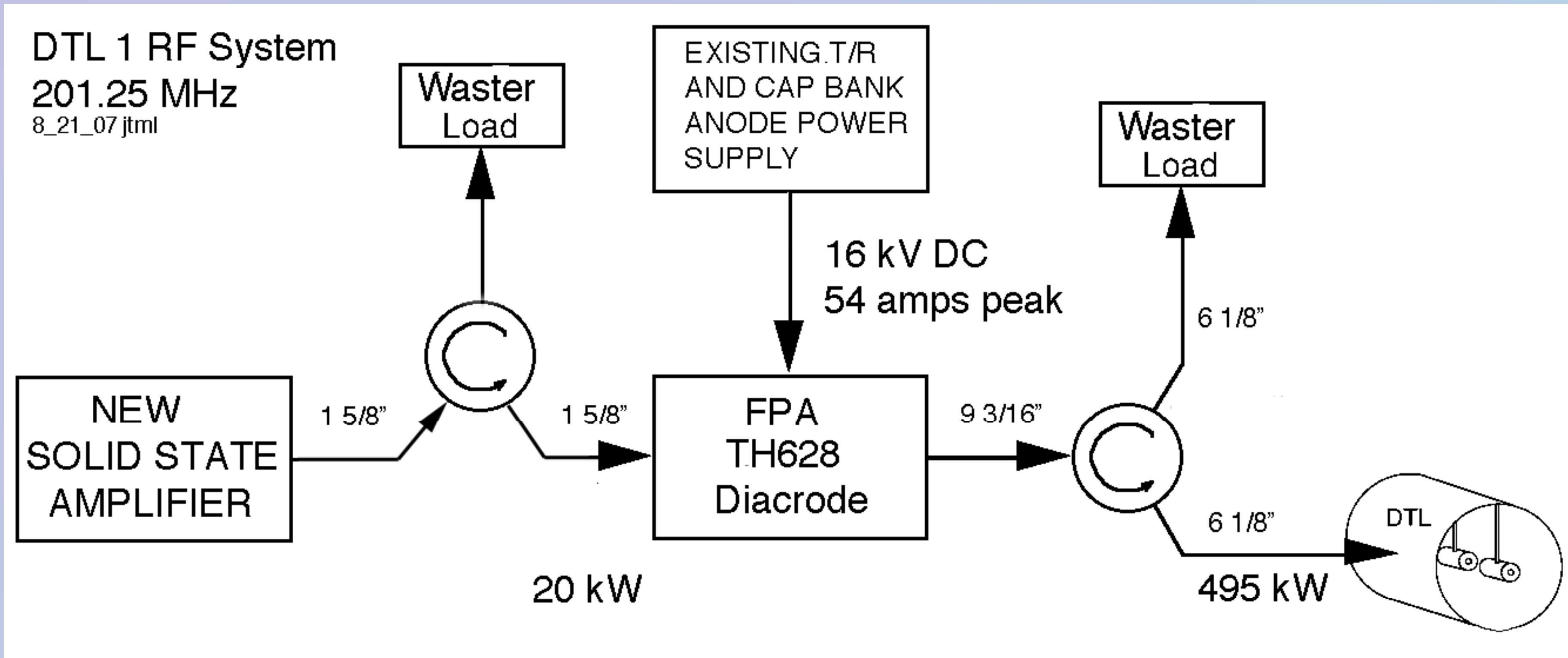
Future RF Power Requirements

All Peak Powers in Megawatts

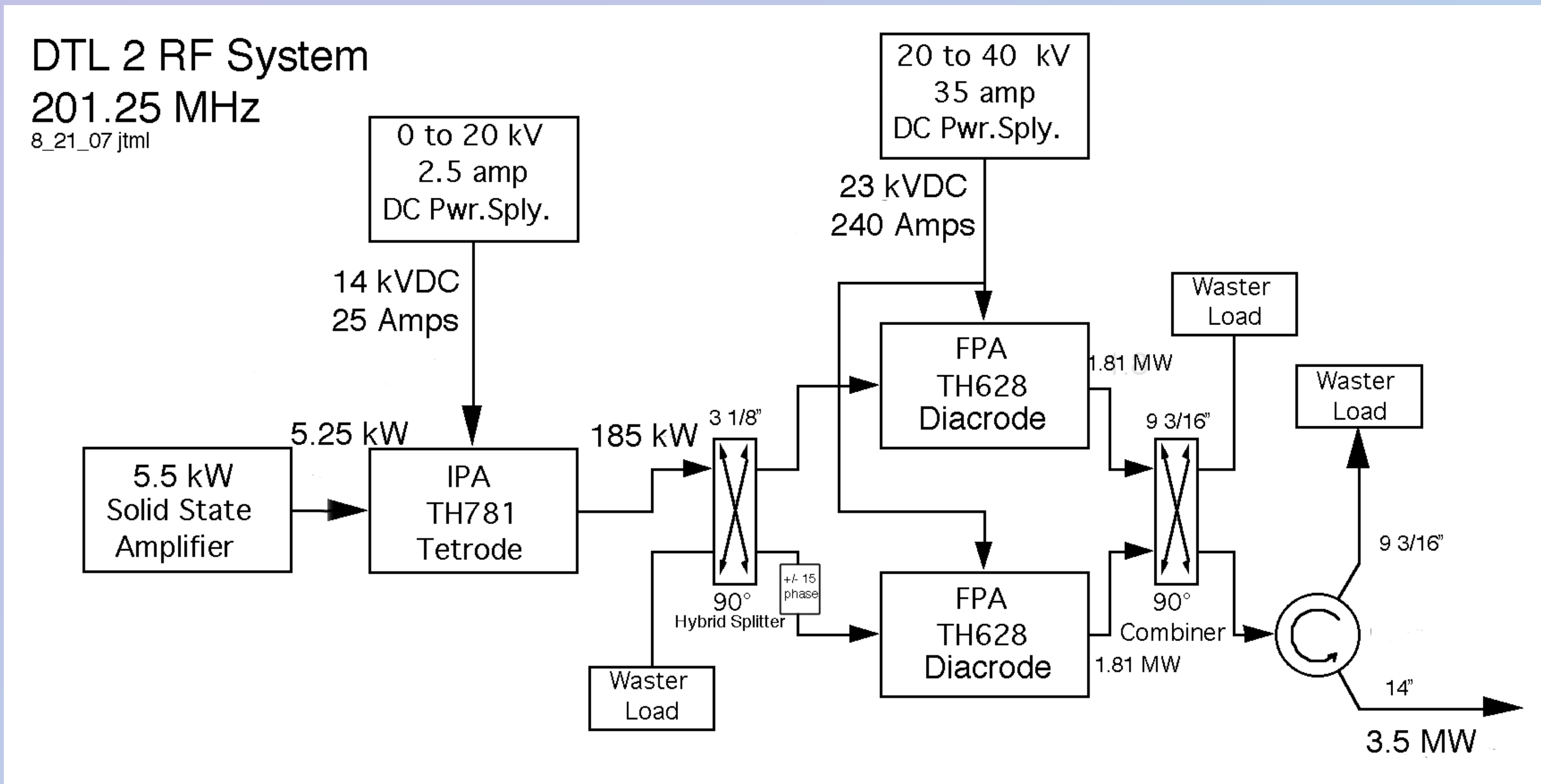
DTL Tank	Energy gain	P_{Cu}	$P_{Cu+16.5\ mA}$	$P_{Cu+21\ mA}$	Goal
1	4.64 MeV	0.38	0.46	0.48	0.5
2	35.94 MeV	2.72	3.31	3.47	3.6
3	31.39 MeV	2.09	2.61	2.75	2.9
4	27.28 MeV	2.49	2.94	3.07	3.2

Tank 2 needs the highest power, and the present final power amplifier (FPA) typically has highest downtime from tube problems

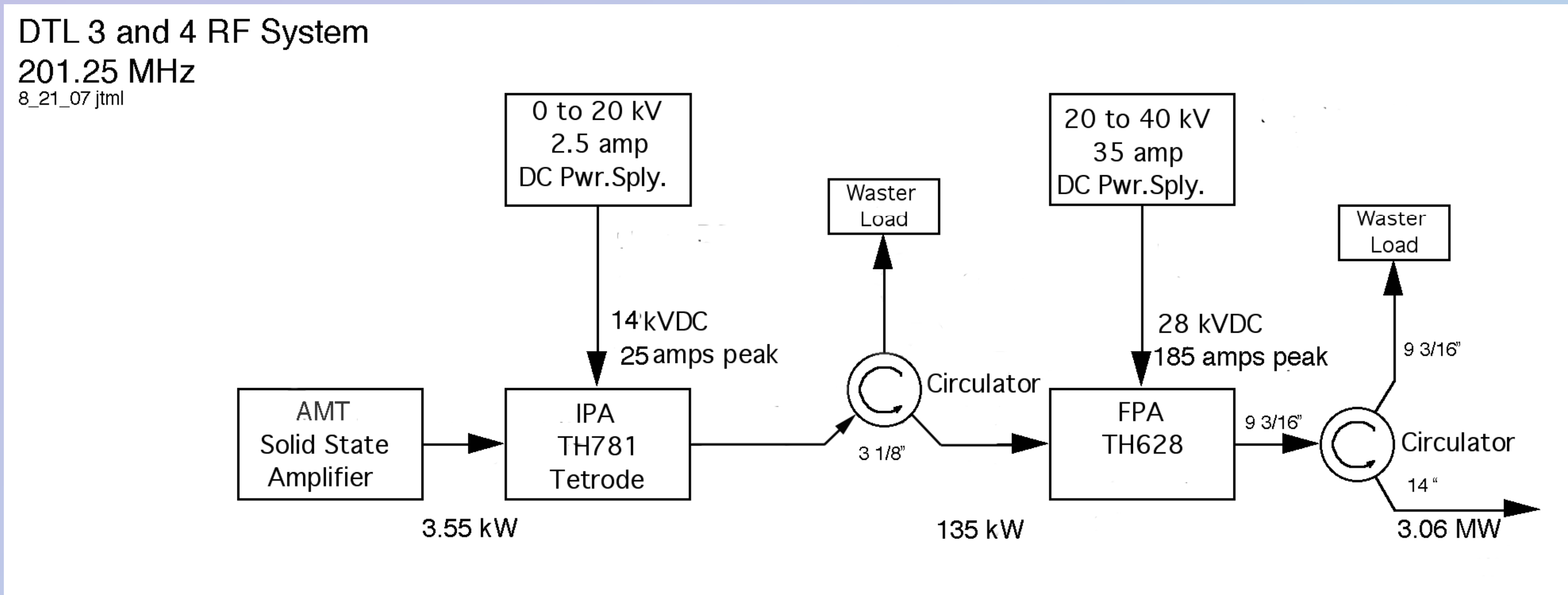
New DTL 1 Amplifier Chain



New DTL 2 Amplifier Chain



New DTL 3 & 4 RF Amplifier Chain



Burle 7835 Triode   Thales TH628 Diacrode

Double-Ended RF Circuit

•Burle (RCA) 7835 triode and Thales TH628 Diacrode are both double-ended tubes

•Require a "slave" cavity on one end (top) of both the input and output terminals of tube*

•Main tuning short at opposite end of tube (bottom)

•Forces TEM voltage standing-wave maximum, centered at active electron region inside tube

•In a typical case in which the active region is 45° long, the voltage varies only 8% over the length of active region rather than 36% for conventional tubes

•Max current density in one end of conventional tubes creates high i^2r dissipation, usually worse in screen grid. This often limits the power capabilities of large power grid tubes at VHF.

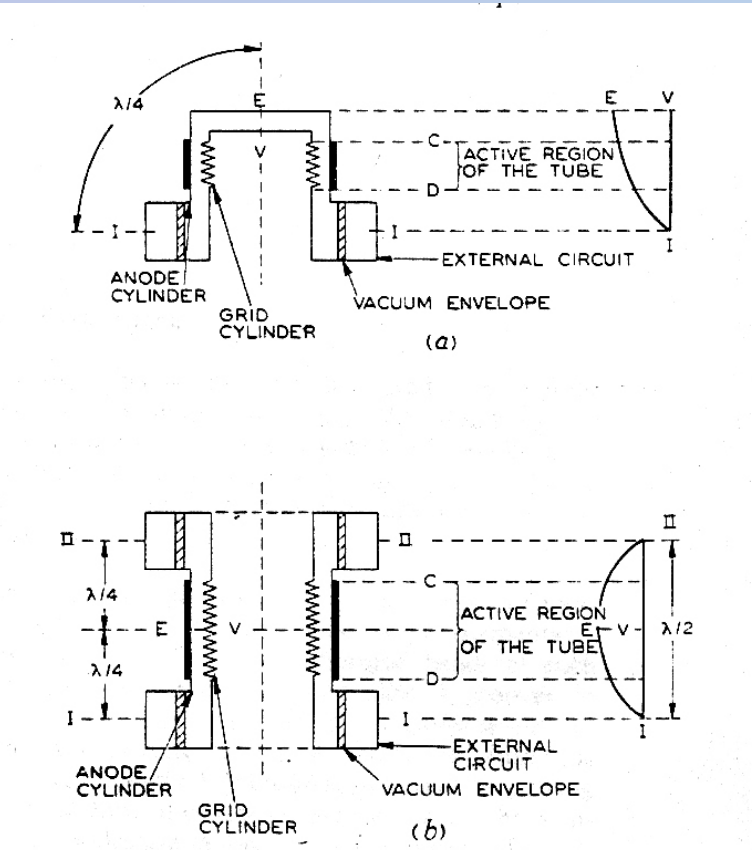
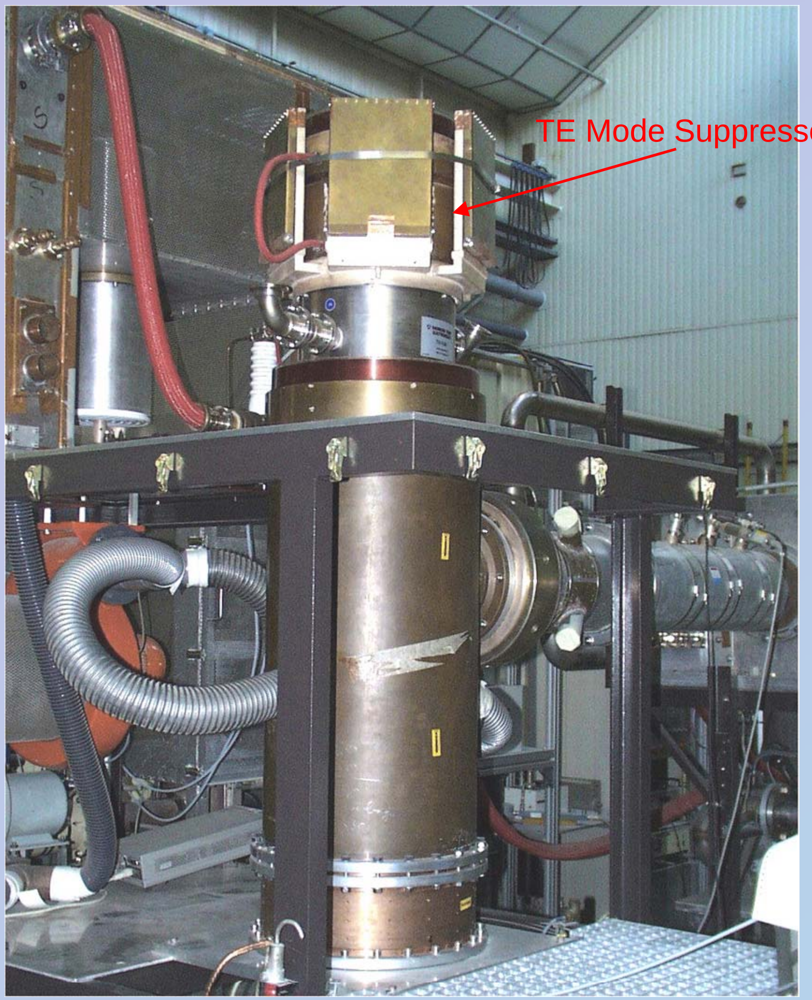


Fig. 1.—Simple longitudinal cross-section of the output circuit for triode: (a) in 'single-ended' arrangement; (b) in 'double-ended' arrangement.

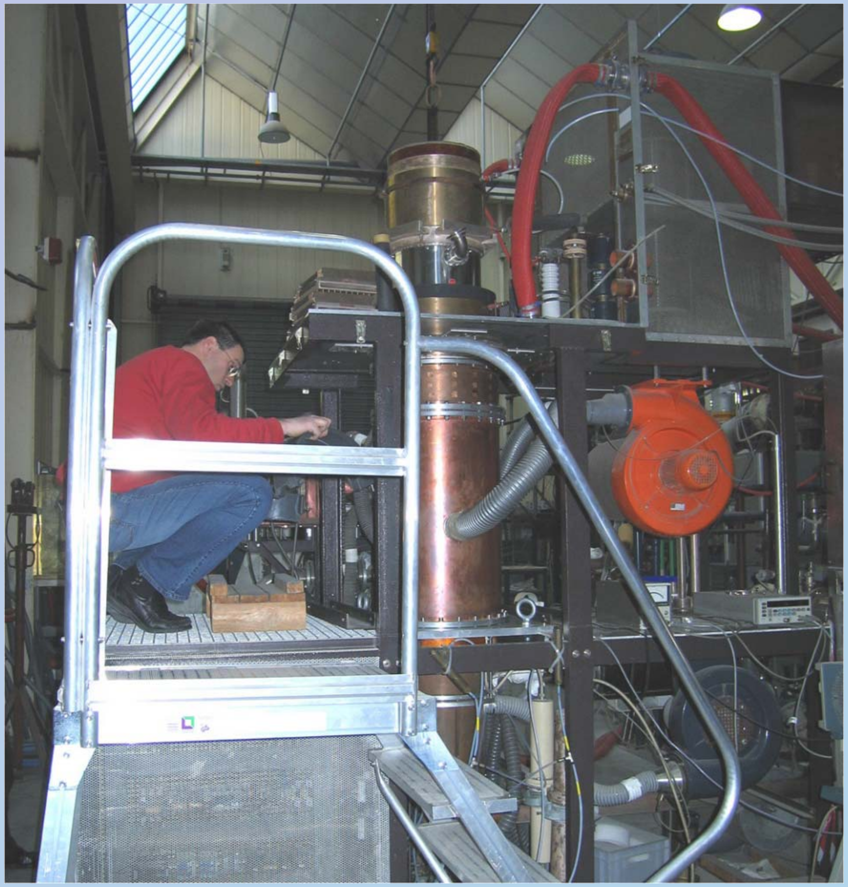
Source: Hoover, "Advances in the Techniques and Applications of Very High Power Grid-Controlled Tubes", IEE, Nov. 1958

TH628 s/n A04 tested in Thonon les Bains 1998



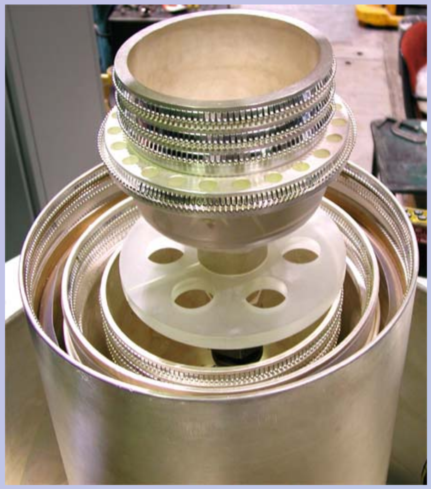
•Peak power output	3 MW peak
•Average power	600 kW
•RF pulse duty cycle	20%
•DC-to-RF efficiency	>60%
•DC plate voltage	26 kV
•Screen (G_2) voltage	1.6 kV
•RF power gain	>14 dB
•Zero drive stability	to >1 GHz

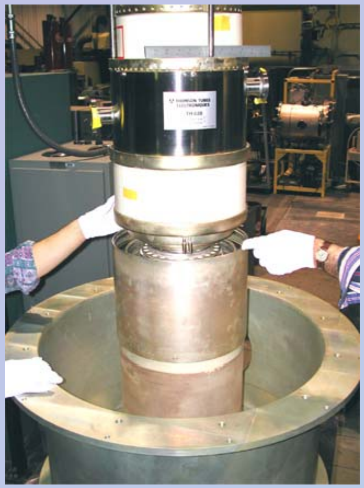
Re-tested Dec. 2007 in Thonon les Bains

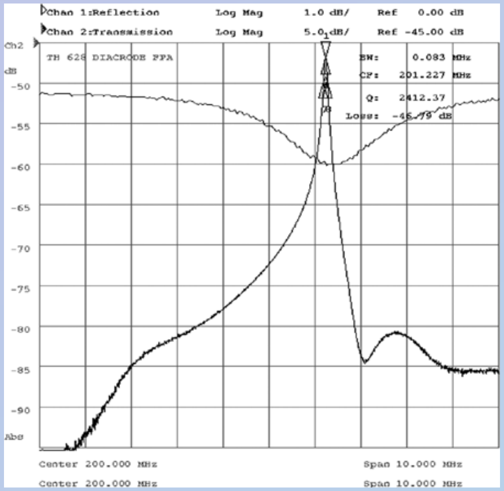


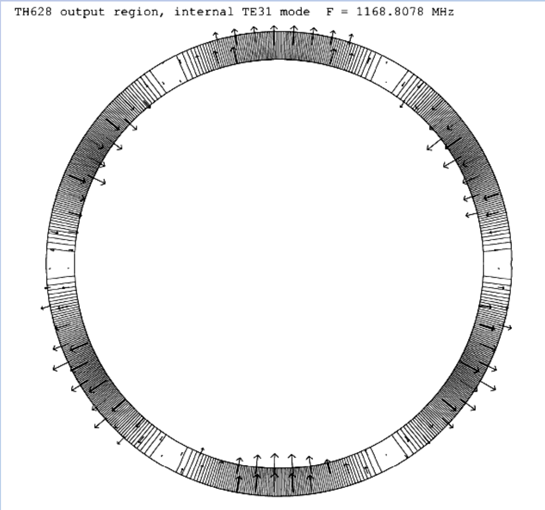
Now Rated for 3.2 MW 15% DF

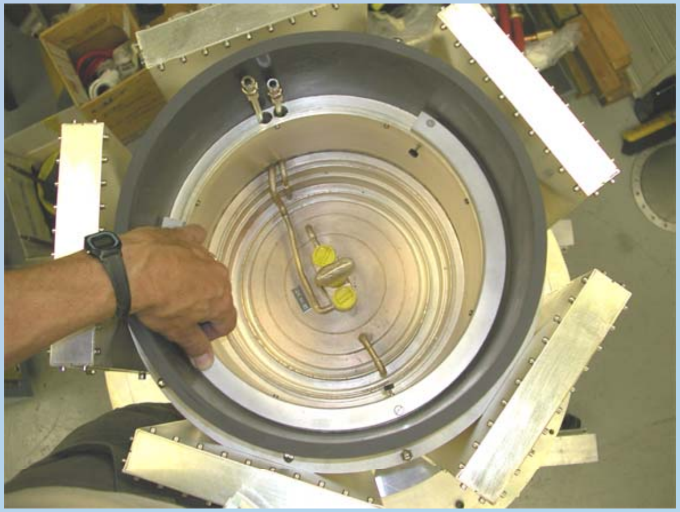
FPA Development at Los Alamos



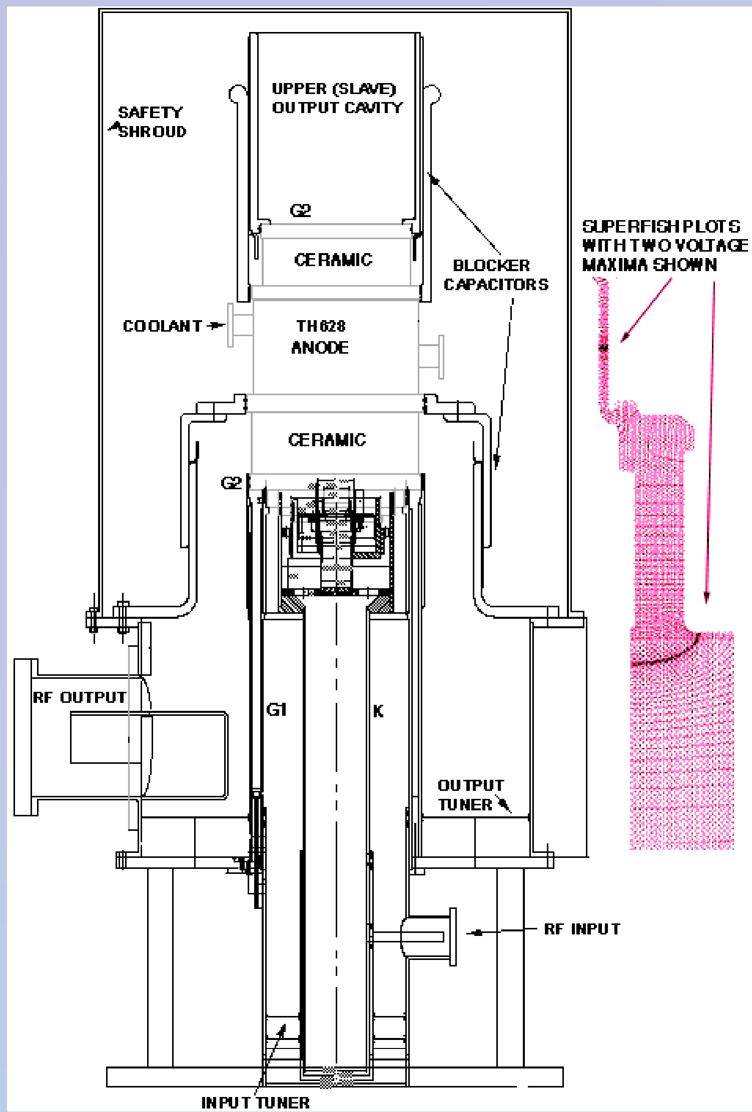




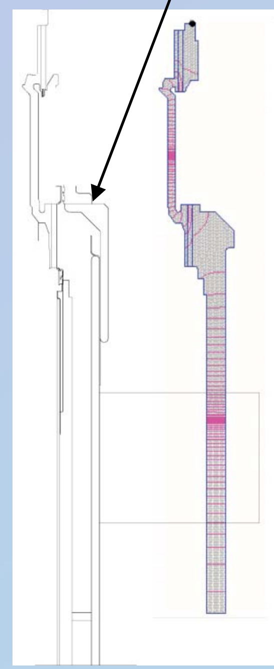




Field Calculations from Superfish



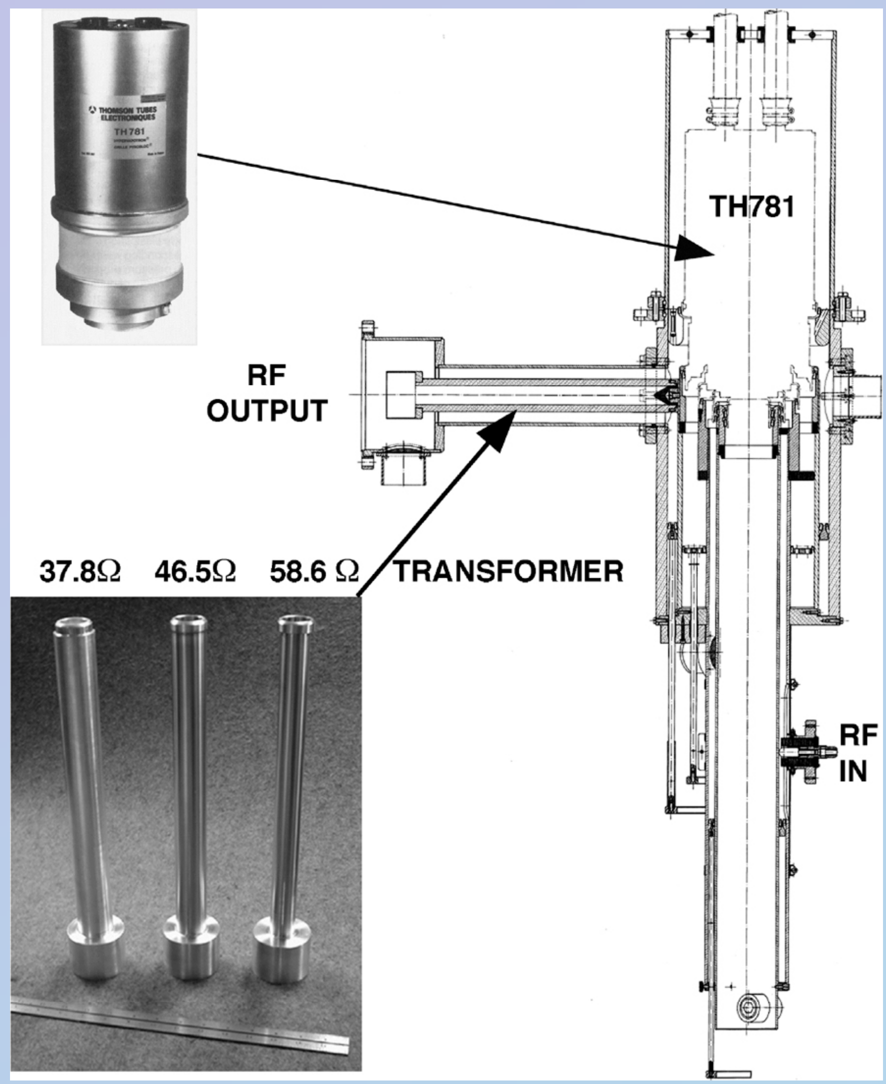
Improved Output Resonator, with Capacitive Output Coupler (2006)



Intermediate Power Amplifier

- **Needed as a driver for the TH628 Final Power Amplifiers**
- **Thales TH781 tetrode selected, due to increasing popularity in many applications, and ability to operate at high DF**
- **Burle 4616 is also capable, but our amplifiers require renewal, 40 years old**
- **DTL 1 won't require this; it will use 25 kW solid state PA**

TH781 in Thales Cavity Amplifier



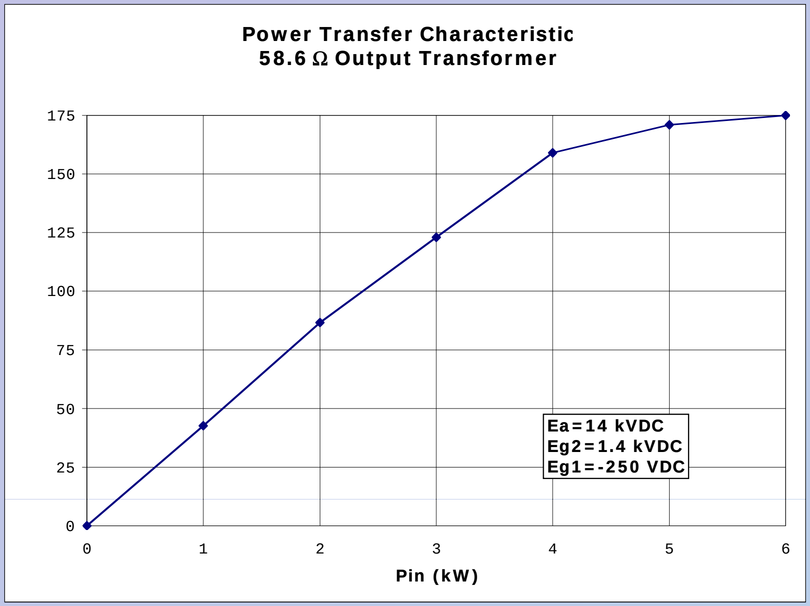
IPA Tested at Los Alamos

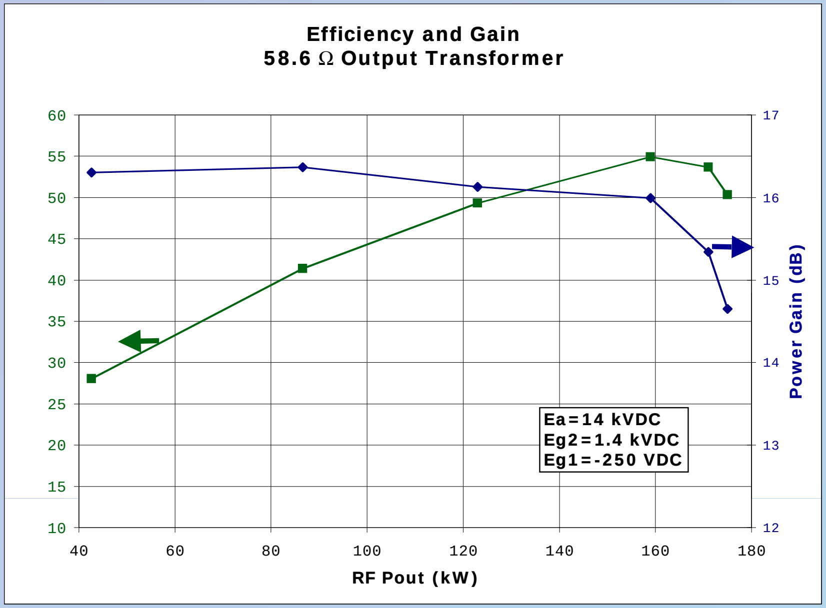
Original using AC Filament Transformer

DC Filament Power Supply

TH781 IPA Test Setup

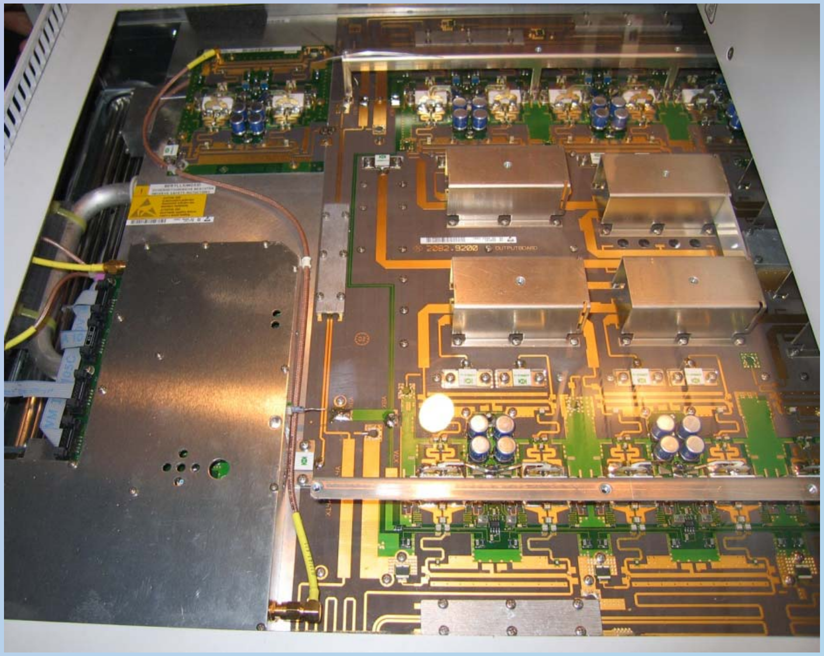
TH781 IPA





- Need 130-185 kW output, will work with existing 5.5 kW solid-state driver amplifiers
- Replaces Burle 4616 tetrode IPA, same performance
- Use same anode power supply as Burle 4616 Tetrode

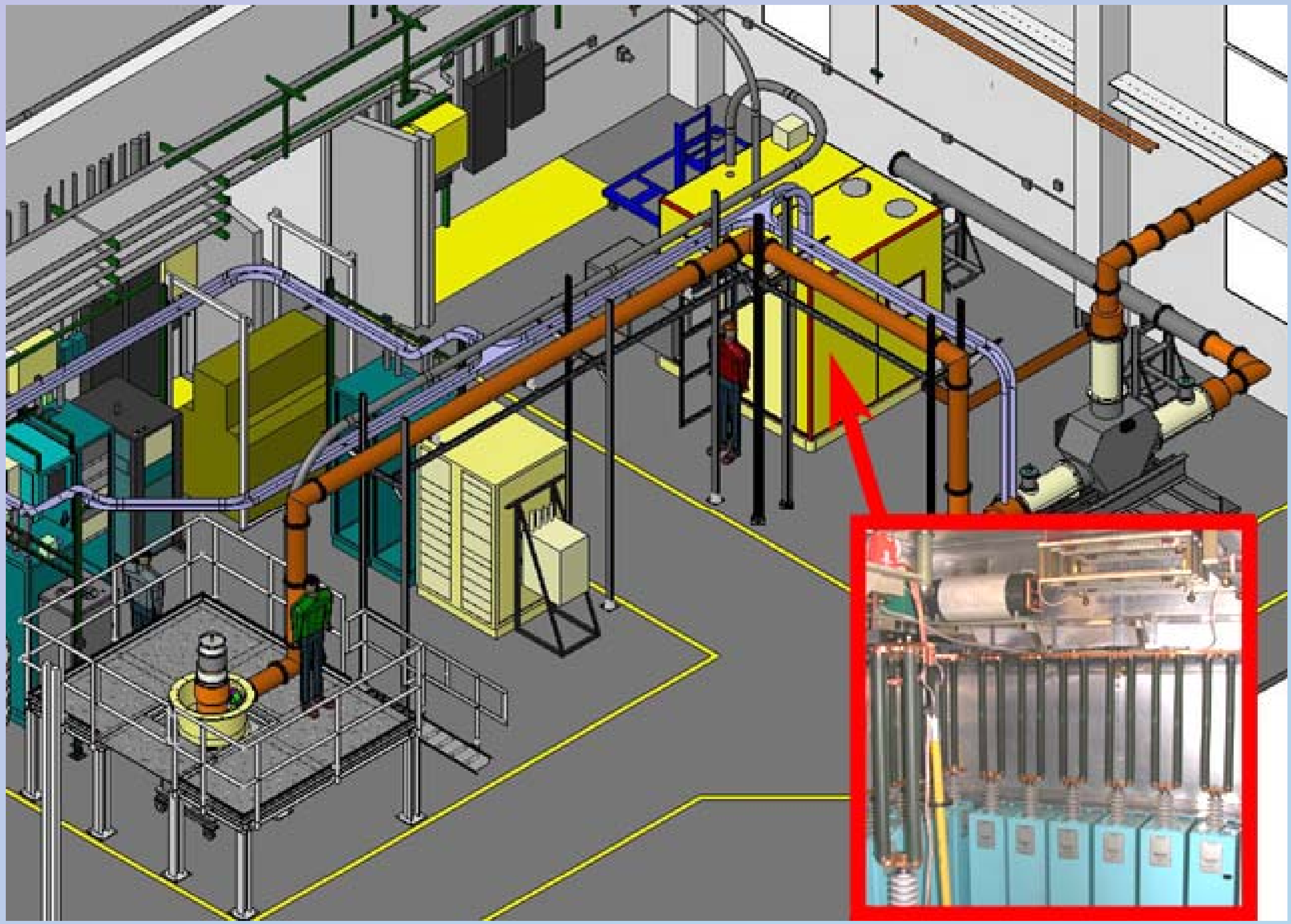
Need 25 kW IPA driving TH628 at DTL1
Example: 10 kW Commercial TV Transmitter



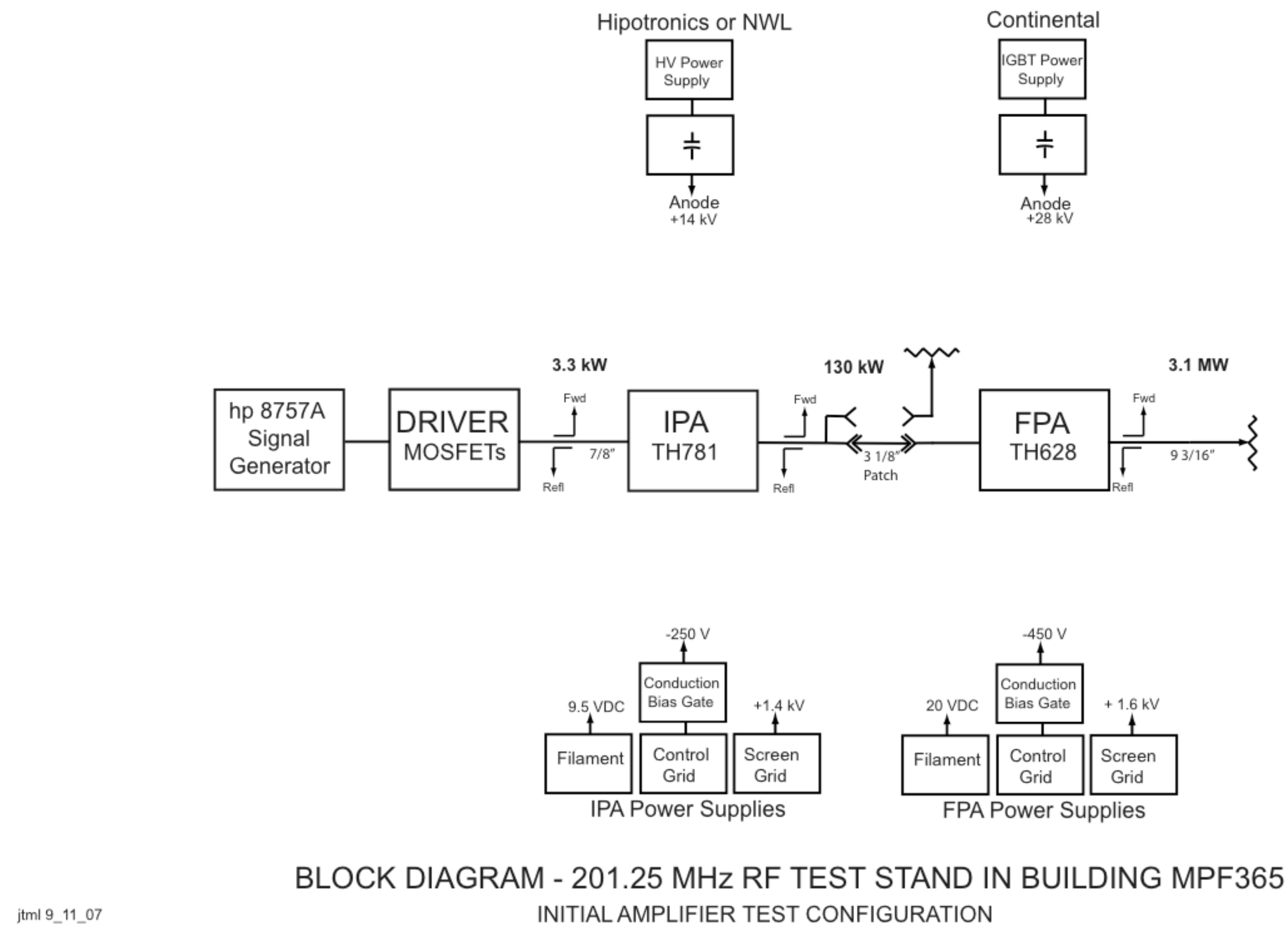
1200 Watt Water-Cooled LDMOS Module

Relocated into Former LEDA Building

Layout of New RF Test Area



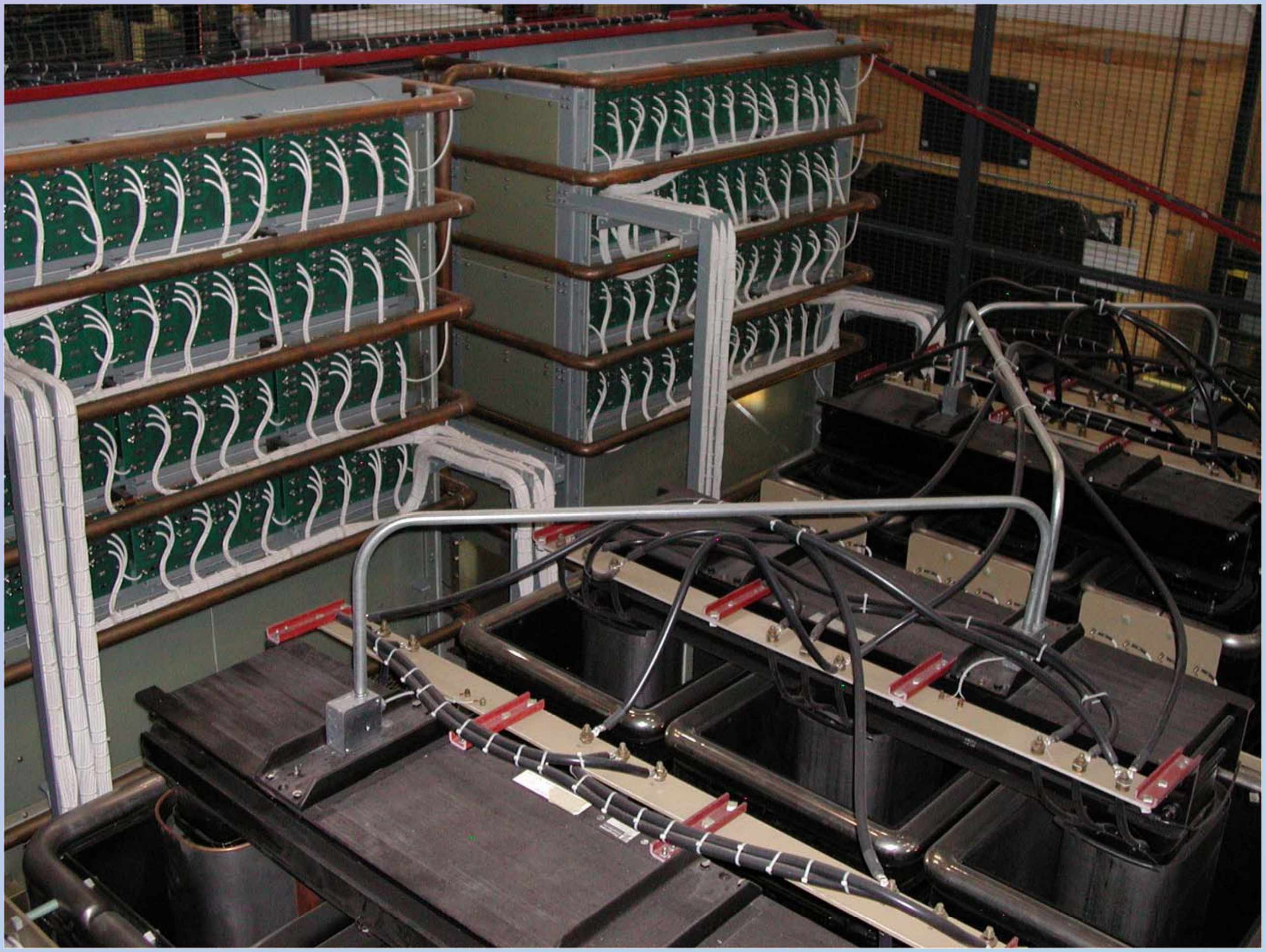
RF Test Diagram



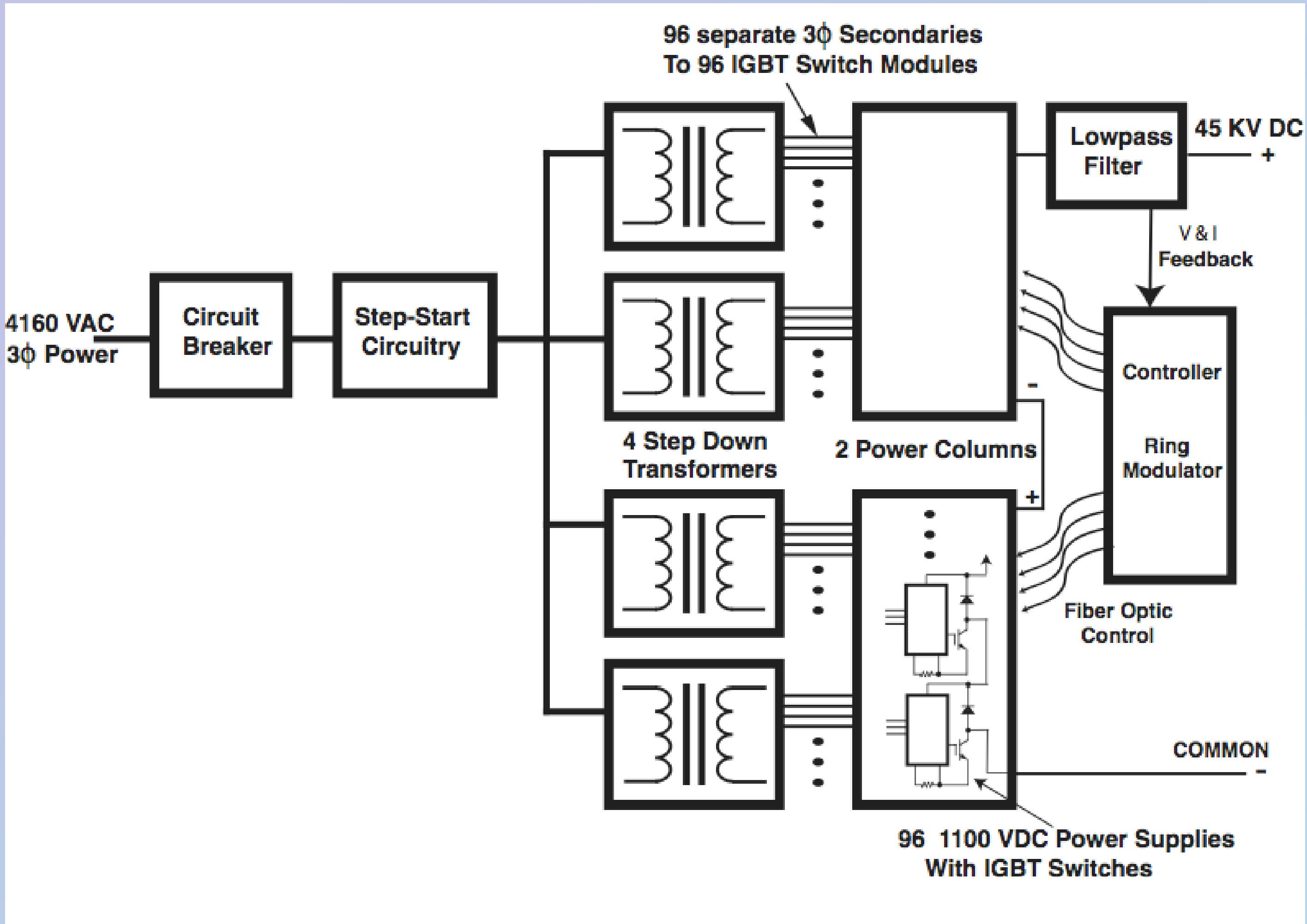
BLOCK DIAGRAM - 201.25 MHz RF TEST STAND IN BUILDING MPF365

INITIAL AMPLIFIER TEST CONFIGURATION

IGBT HV Power Supply
Continental Electronics Corporation



Converted -95 kV Beam P.S. to +45 kV for Anode Power Supply



Testing Power Supply
0.4 Amp @ 20 kV DC

20K Ohm Exterior Load

- Built by NWL in 1980s
- Test load for 100 kV 5 amp beam PS
- Air cooling, with fan
- Draws 1.4 amps @ 28 kVDC
- Reduces efficiency of IGBT PS by ~3%
- May modify - raise value to 50K Ohm

88 kJ Capacitor Bank

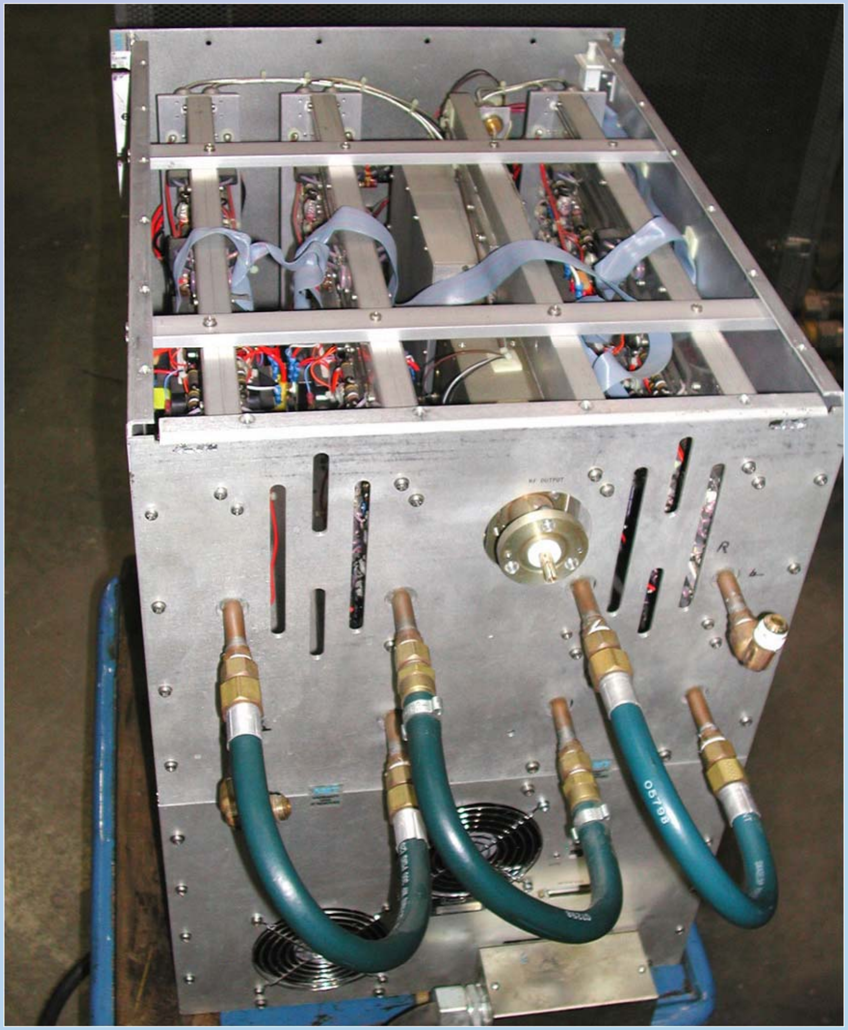
Inside LANL Capacitor Bank

Inside LANL Capacitor Bank

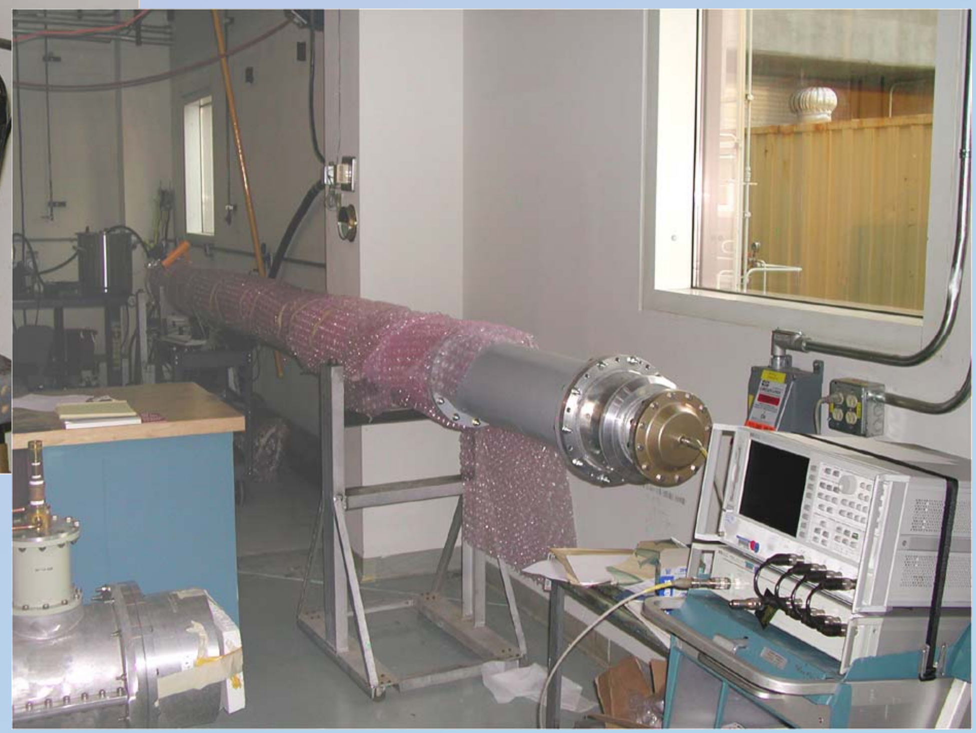
Filament, Screen and Grid Power for TH628

Solid State Driver

- 54 dB Gain
- 5.5 kW Peak Output
- Water Cooling
- (4) Installed 1995
- (32) MRF176GV MOSFETs
- Extremely Reliable
- Will be Re-used



Water Load Test



See Karen Young's Talk on Friday

Ionized Water Loop

AFT Circulator Sweep Test

< 0.07 dB loss [S21] at f_{center}
< 0.15 dB loss +/- 3 MHz
≥ 26 dB isolation [S12] at f_{center}
≥ 10 dB isolation +/- 3 MHz
< 1.05:1 VSWR at f_{center}
35.5 cm coaxial line
1728 kg, ≈ 3 m long