

**Project X**  
Project X



*RF Power Sources*  
*for*  
**Project X**

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*Fermilab*

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## Outline

- *RFQ 162.5 MHz, 2 Bruker 75 kW solid-state*
- *Coupler test stand 162.5 MHz, 10 kW Thomson solid-state amp*
- *Coupler test stand 325 MHz, 10 kW Bruker solid-state amp*
- *Coupler test stand 650 MHz, 30 kW Comark IOT amp*
- *Horizontal test stand 1.3 GHz, 30 kW CPI IOT amp*
- *Collaborative efforts on Solid-state and Magnetrons*



*Front view*

*Rear view*

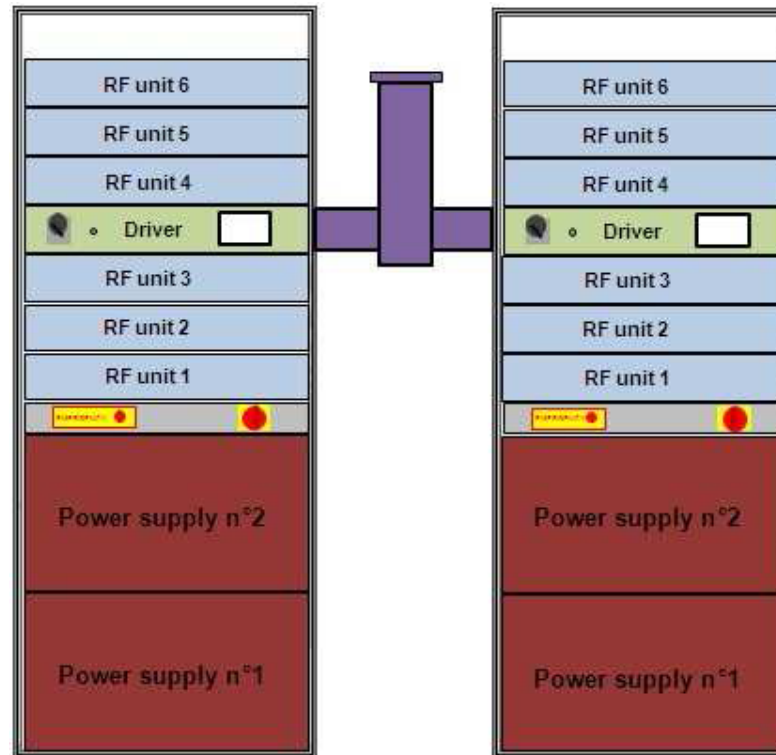
*Solid-state 75 kW RFQ amplifier*



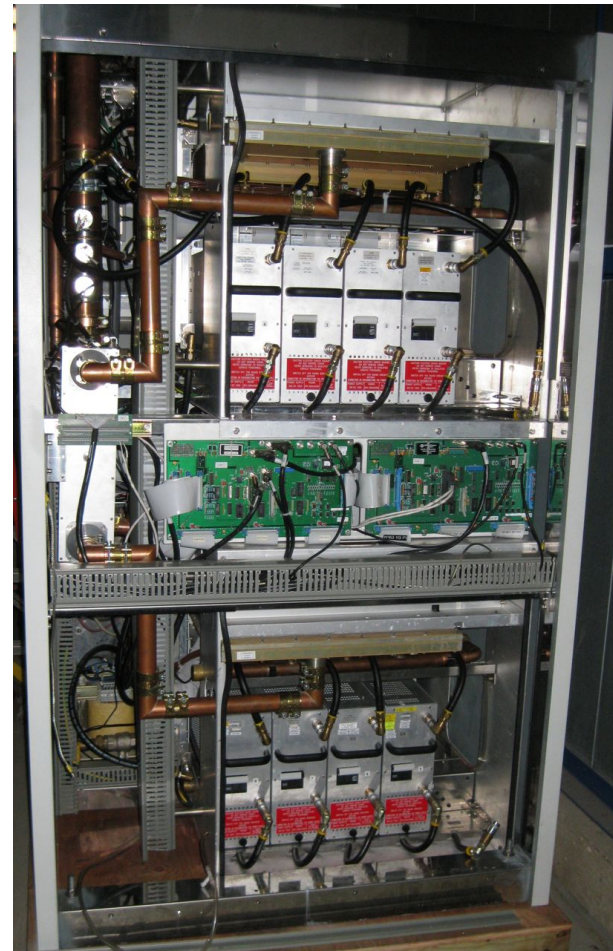
## RF Sources



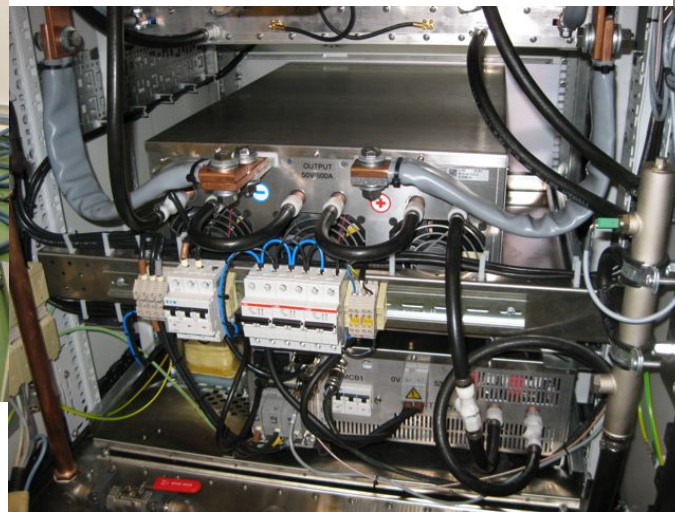
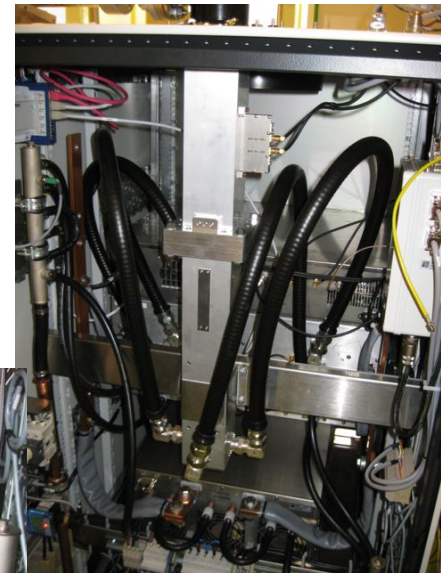
*Each RF unit  
Delivers approx 7 kW  
RF modules and  
Power supplies  
Are water cooled  
For enhanced reliability*



*75 kW RFQ amplifier*



*Refurbished 162.5 MHz VHF TV transmitter  
Water cooled Thomson 10 kW Solid-state*



*10 kW 325 MHz coupler test stand solid-state amplifier*



*325 MHz 10 kW Solid-state amp for coupler test stand @ MDB*



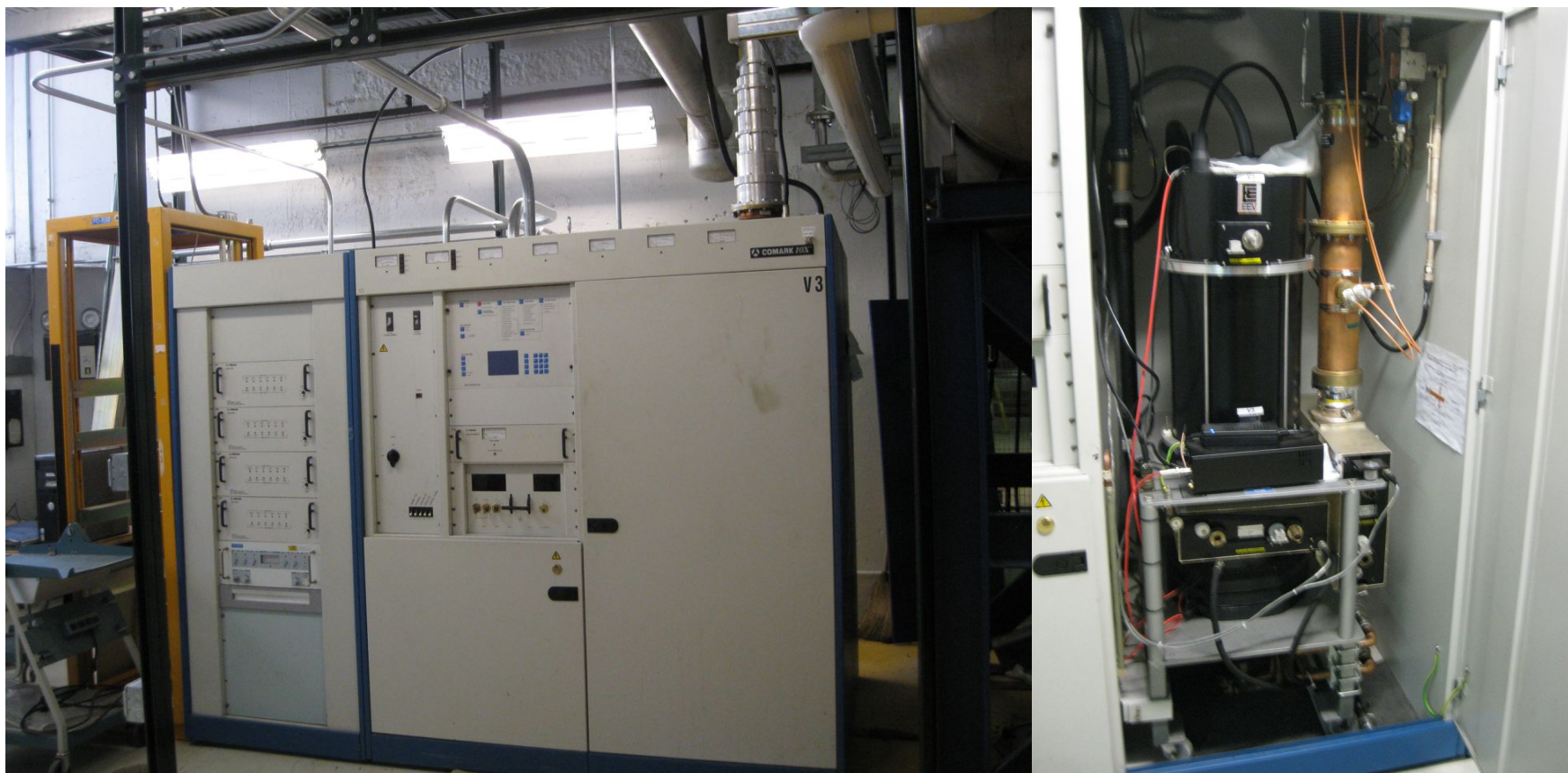


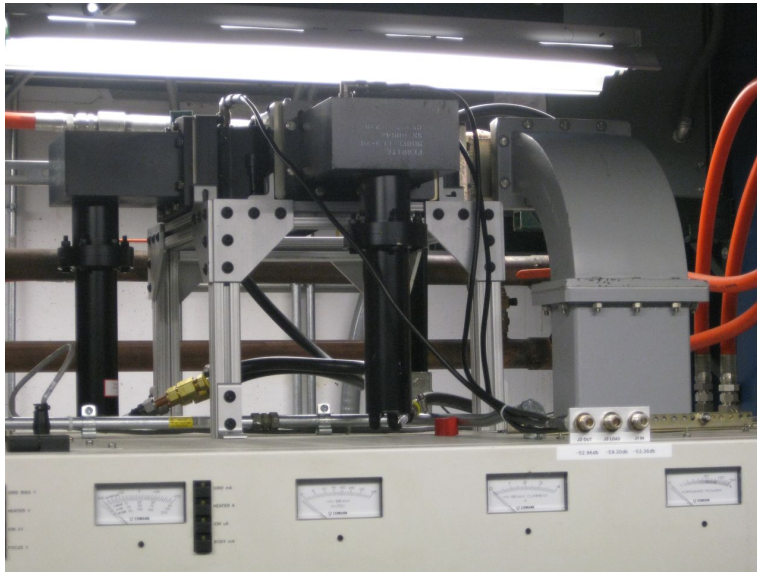
*650 MHz Comark 30 kW IOT with Ferrite Circulator @ MDB  
For Horizontal Test Stand*





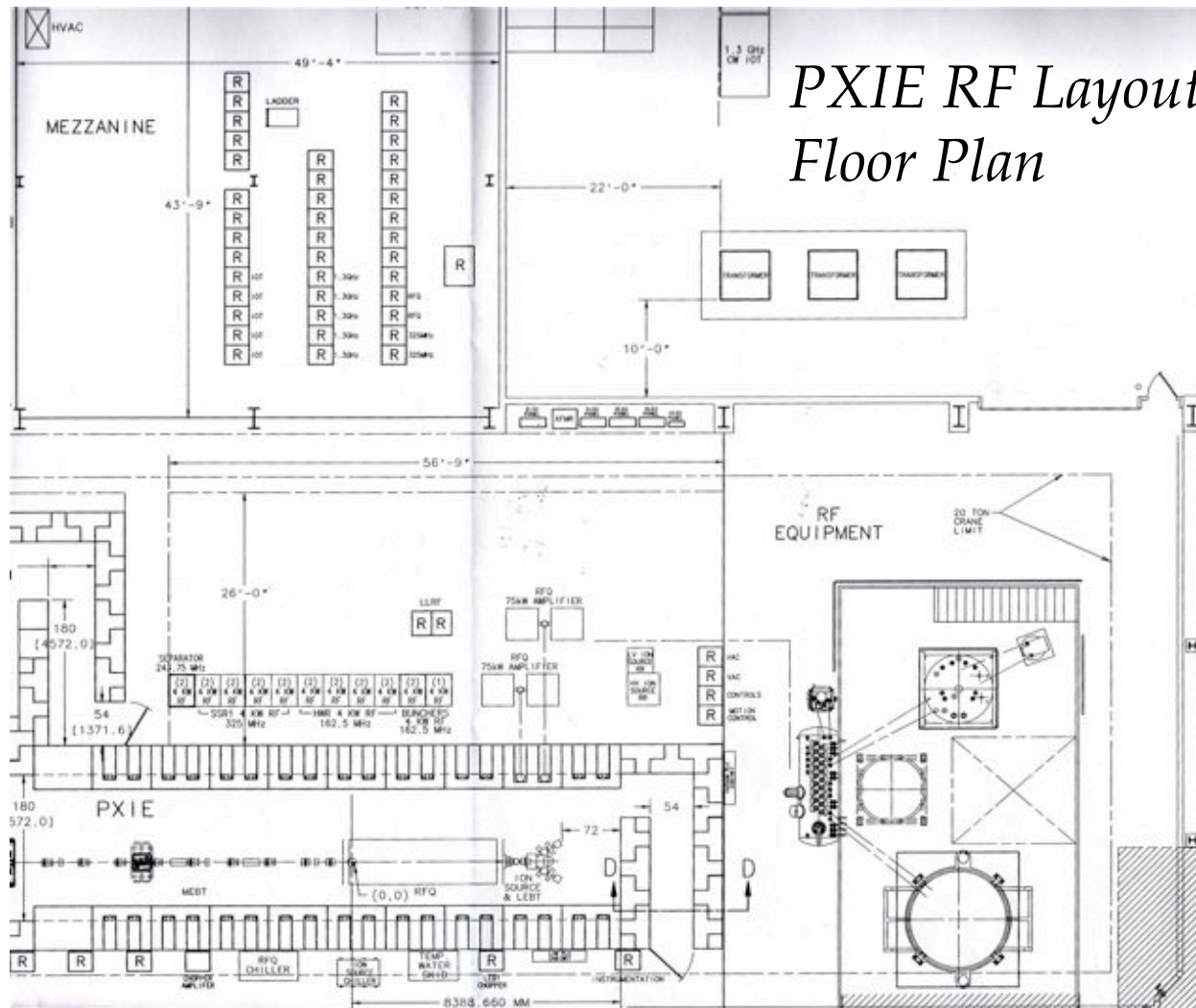
*650 MHz 30 kW IOT for coupler test stand @ MDB*





*1.3 GHz 30 kW IOT  
@ MDB for horizontal test stand*

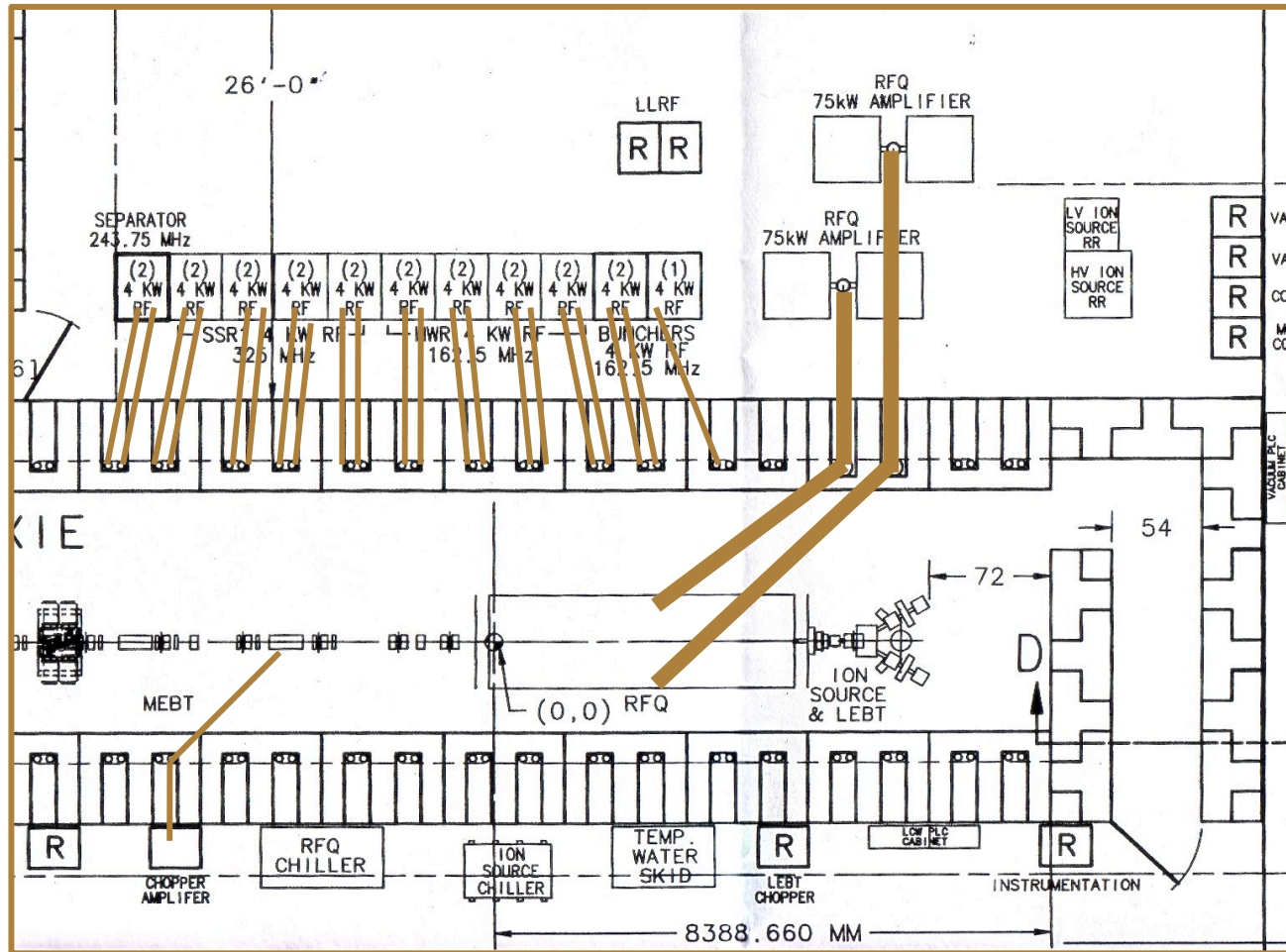




PXIE RF Layout  
Floor Plan



Coax RF Distribution





## Collaborators

- *SLAC: Integration of 650 MHz solid-state modules*
- *BARC: Development of multi kW solid-state at 325 MHz*
- *RRCAT: Development of multi kW solid-state at 650 MHz*
- *GMRR: Development of high efficiency solid-state modules at 325 & 650 MHz on Phase II SBIR*
- *Muons Inc: Development of injection locked 50 kW 650 MHz magnetron source via STTR fast track*



## *RF Sources*



# *HIGH-EFFICIENCY RF POWER-AMPLIFIERS FOR PROJECT X*

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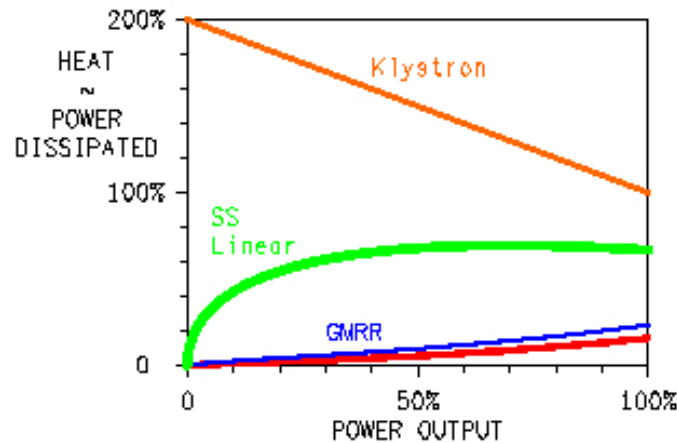
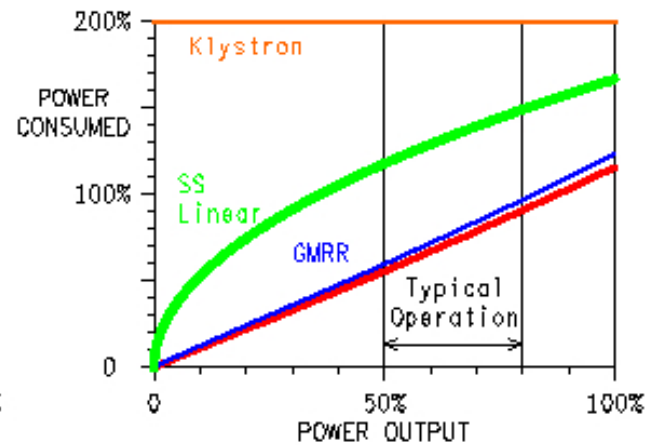
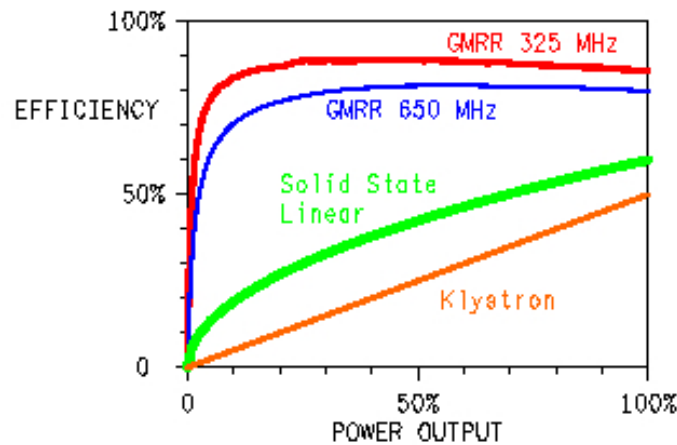
*f.raab@ieee.org*

*SBIR Phase I and Phase II -- DE-SC0006200*





### EFFICIENCY - WHY?

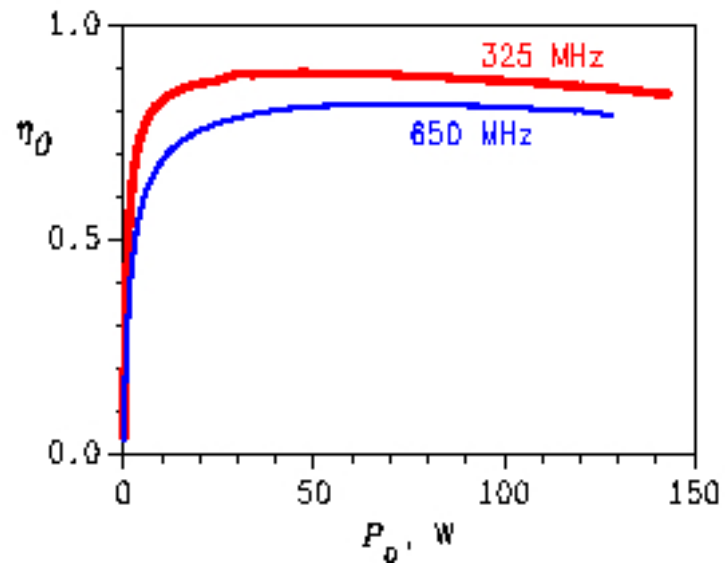
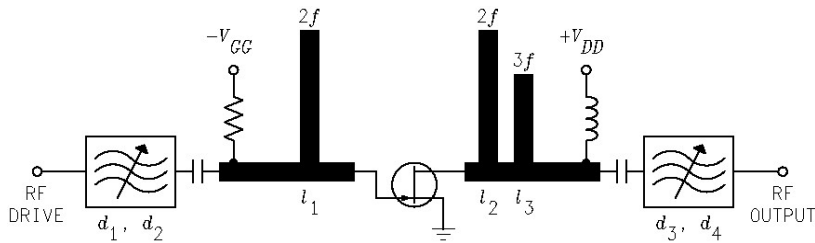


- **Operating cost**
- **Cooling requirements**
- **Reliability**



### RF-POWER AMPLIFIER

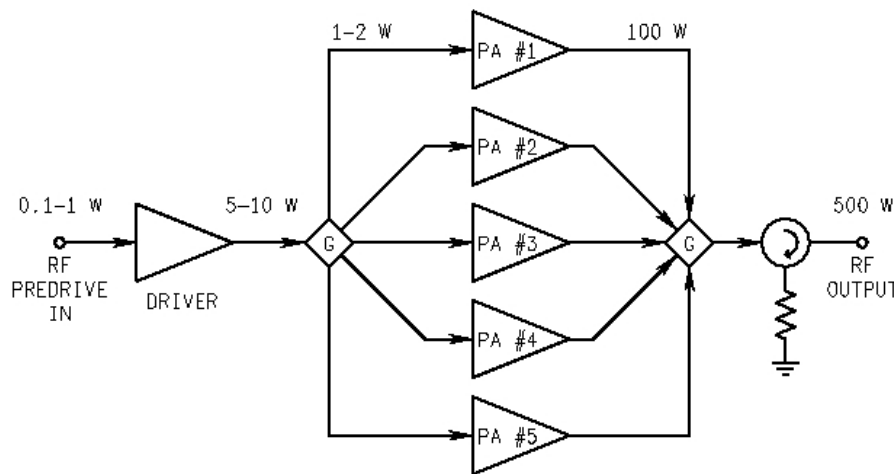
- 120 W
- GaN FET
- 325 MHz - 86%
- 650 MHz - 80%



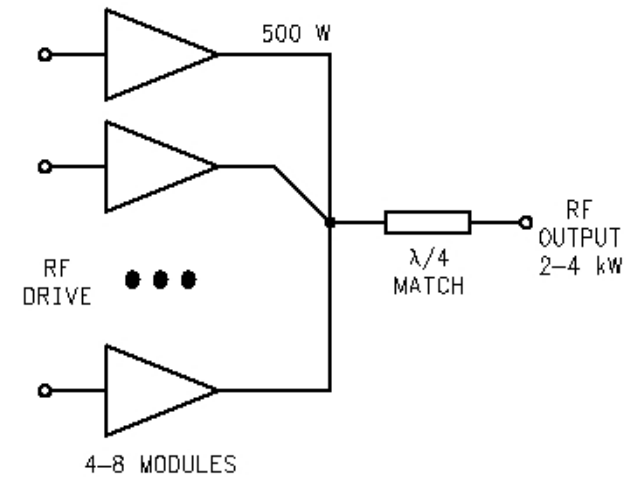




### COMBINING



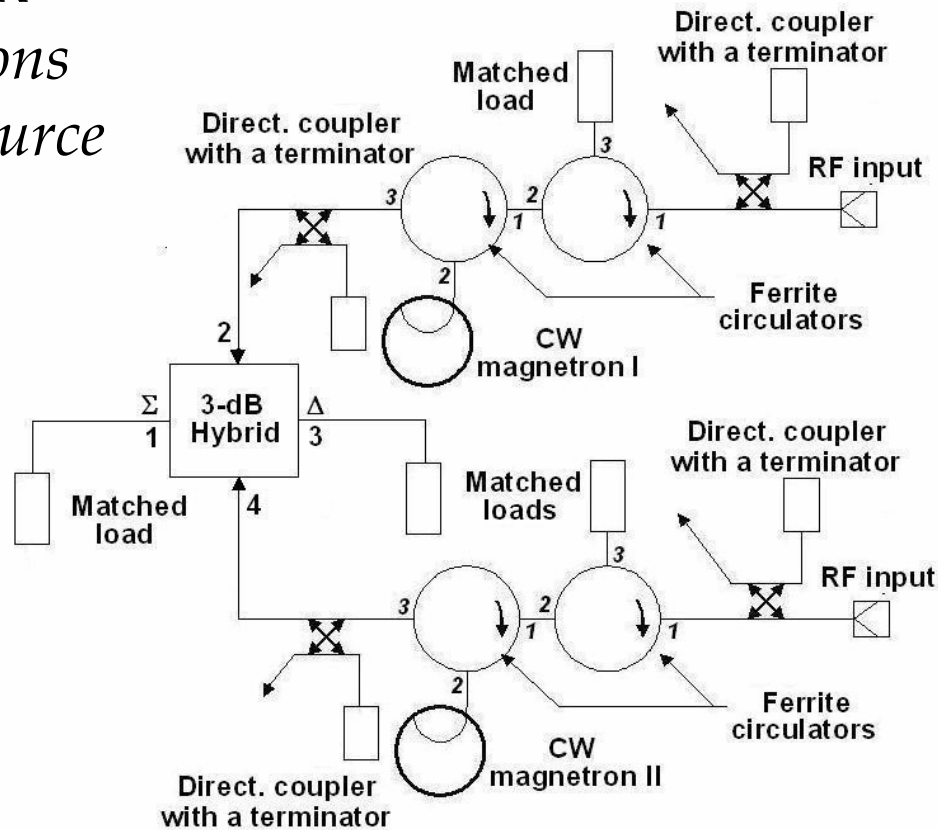
- BASIC MODULE
- 5 PAs
- Hybrid combiner
- 500 - 600 W



- HIGHER POWER
- 2 - 8 PAs
- Radial combiner
- 1 - 4 kW



*Proposed Fast Track STTR  
Dual 650 MHz Magnetrons  
Paraphrased 50 kW RF Source*





Why magnetrons?

- *Magnetrons exceed 80% efficiency, goal 50% minimum in paraphase mode.*
- *In quantities of 50 stations 30 kW magnetrons \$8K \$2-3 per Watt for system of two paraphased less than half the cost of other solutions*
- *Injection locking is proven technology*
- *Gain on order of 15 dB requiring 500 watts drive power*
- *Proven highly sophisticated LLRF controls for paraphasing*
- *Need to measure phase noise performance*



## Summary

- *Significant progress at all frequencies over last year*
- *Four test stands in various stages of development*
- *RFQ amplifiers and circulators on order for delivery June 2013*
- *PXIE floor plan at CMTF converging to final layout*
- *Healthy collaboration with partners in RF Source development*