An Energy-Efficient RF Power Source for the Jefferson Laboratory CEBAF Linac*

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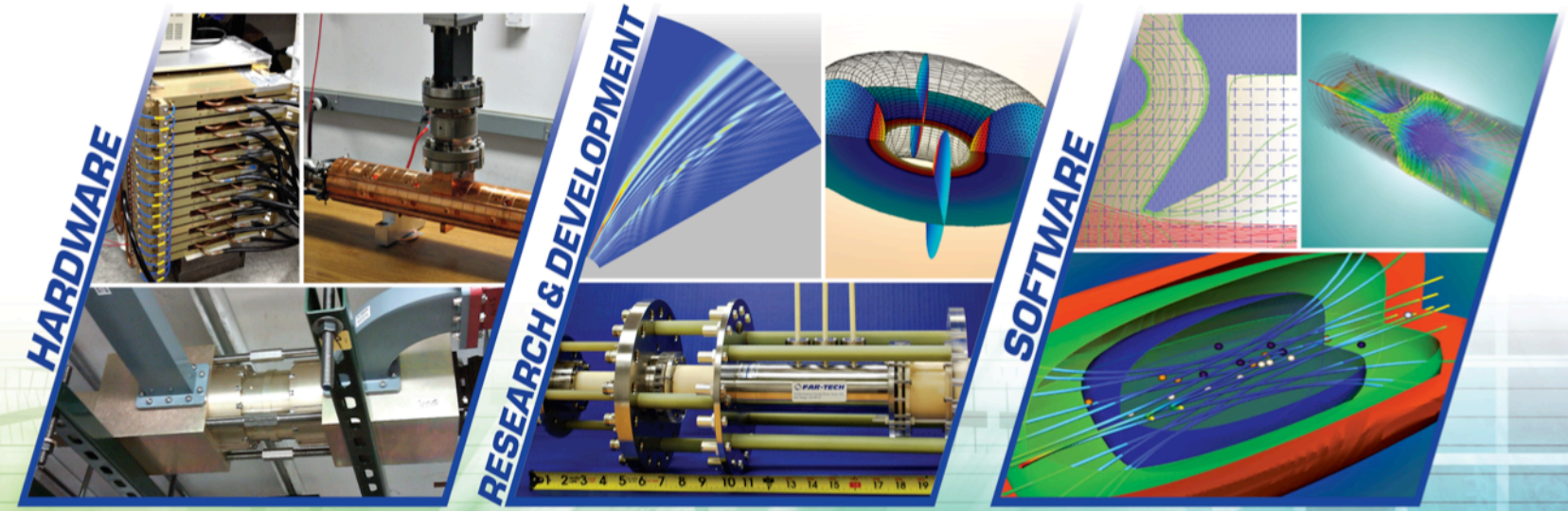
Outline

- Company intro/capabilities
- Project Goal
- JLAB Power Amplifier and Solid State Amplifier
- Final test results
- Commercialization
- Conclusion

Acknowledgement to: R. Nelson, JLAB

FAR-TECH

CUTTING-EDGE PLASMA & ACCELERATOR SCIENCE & TECHNOLOGY



FAR-TECH, Inc. Management and Facility

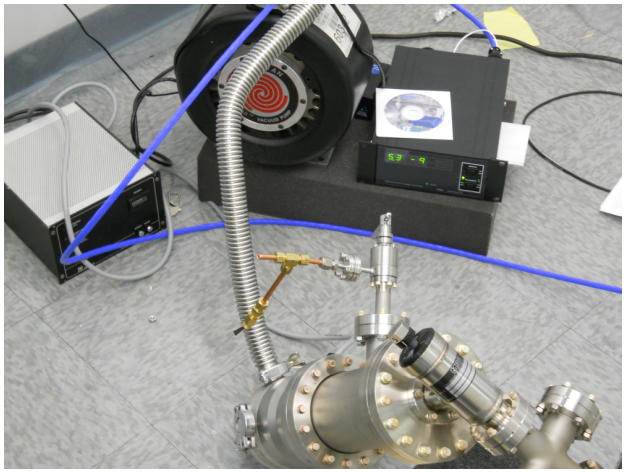
- Located in San Diego, CA
- Founded in 1994, formerly known as Fusion and Accelerator Research (FAR), to pursue fusion and accelerator related research, technology and development.
- Core staff of over 10 PhDs Physics/Engineering
- Facility:
  - Linux cluster (88 processors) with 96GB of memory via Infiniband connection; 15 TB redundant storage
  - RF, UHV, laboratory and assembly

RF Test and Fabrication at FAR-TECH, Inc.

Capabilities:
CAD, HFSS, ACE3P modeling
RF test equipment
Class 1000 clean room
Vacuum station, RGA
Relationship with machine shops
Access to CNC equipment

RF Test Area

Soft-wall cleanroom

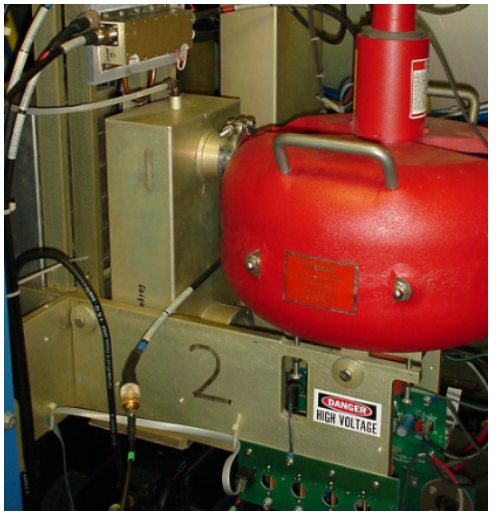


Vacuum equipment

JLAB Solid State Amplifier

Motivation:

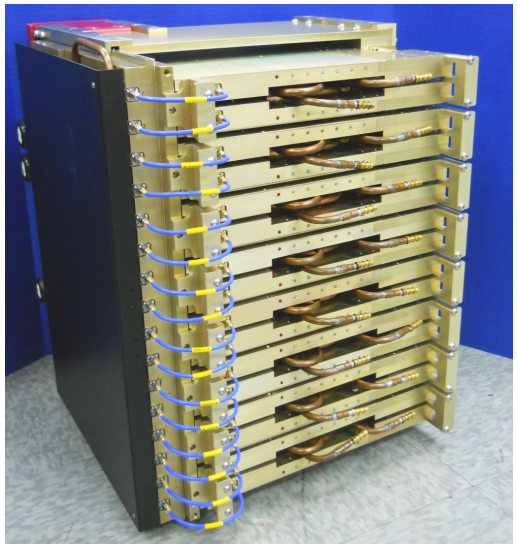
- Present klystrons are inefficient (25-28% linear).
- Some nearing end-of-life.
- Replacements are becoming more costly.
- Solid-state amplifier option is interesting for many projects.



Klystron

Features:

- Compact (20” x 19” x 22” : L/W/H)
- ~55% efficiency, linear
- Graceful degradation
- Possibly long lifetime; simple repair



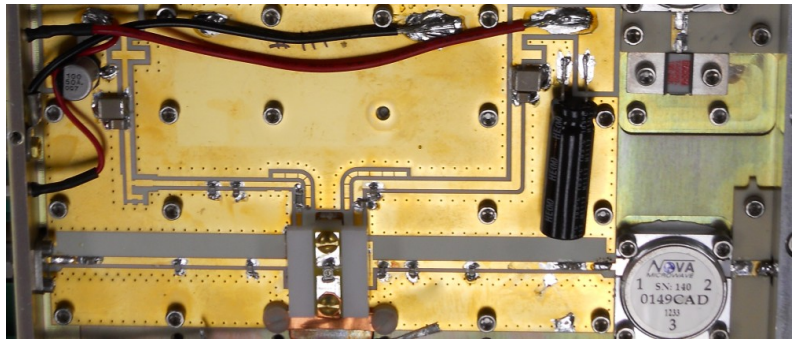
Solid-State

Specifications:

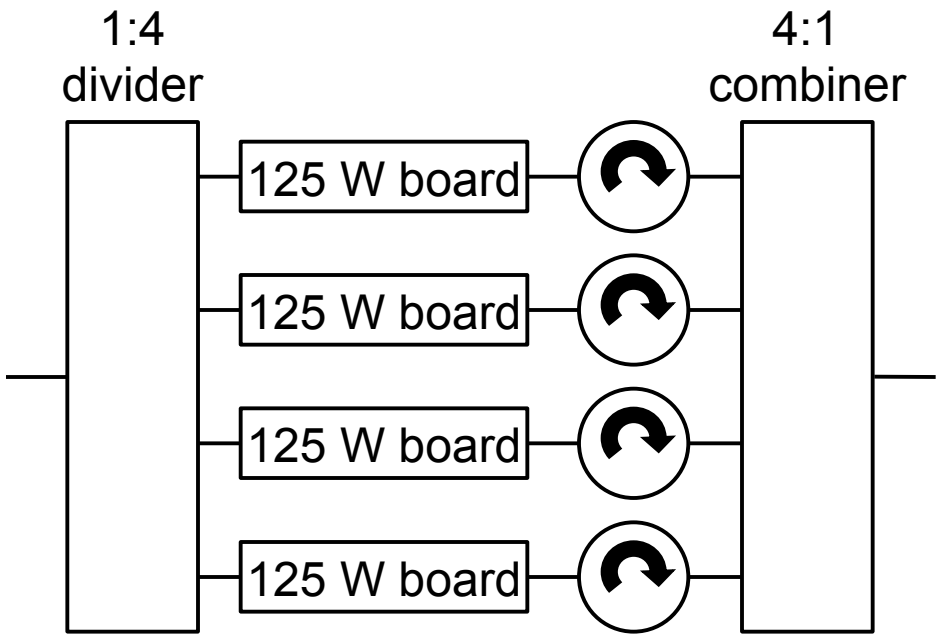
- 1497 MHz CW Operation
- 6.5 kW, Linear Mode

Transistor Board and 500W Module

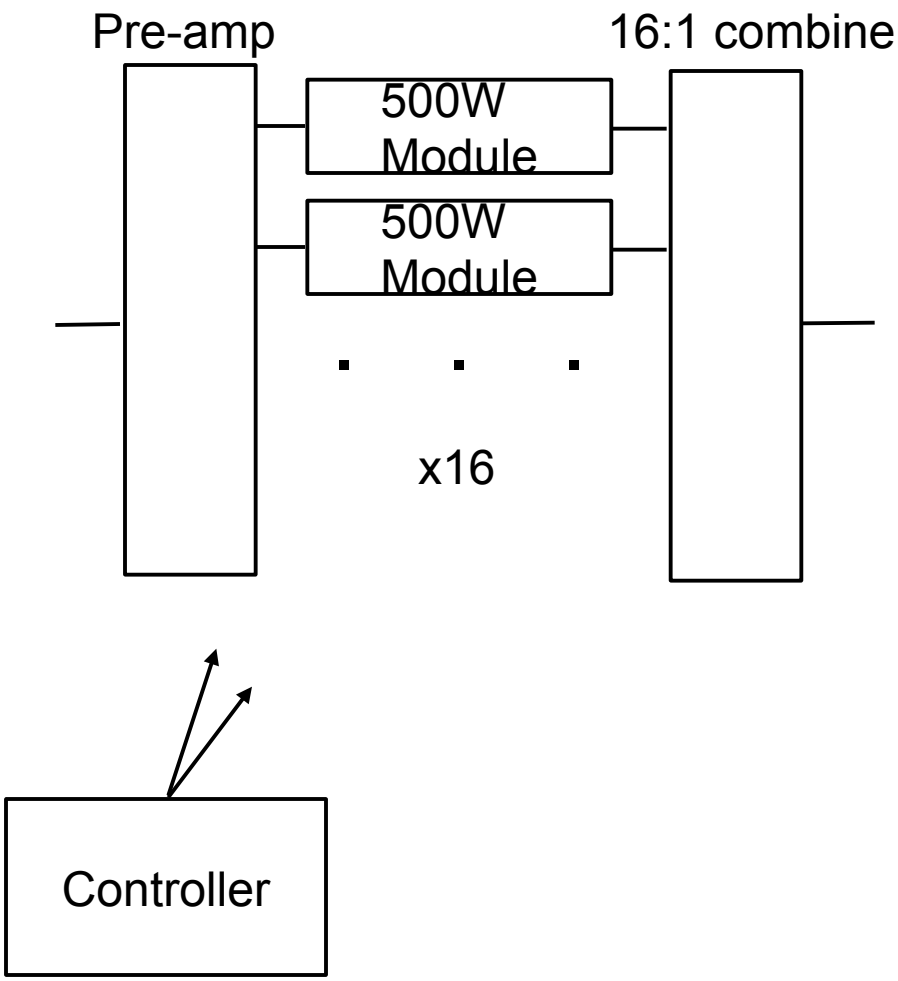
Basic unit: 125W board and Circulator

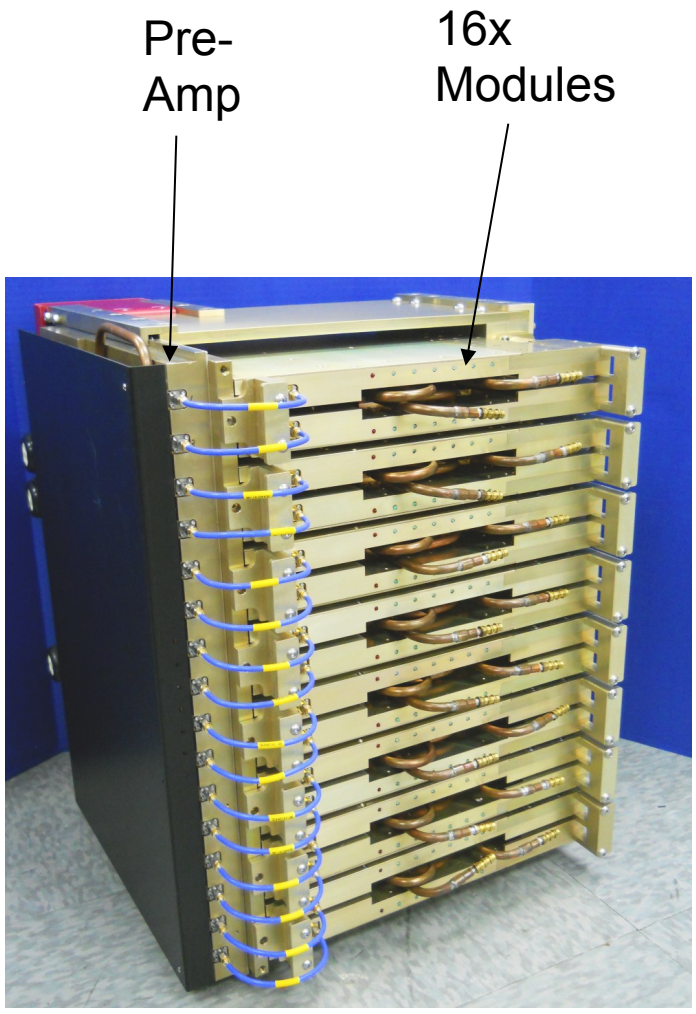


4X basic unit: “500W” module

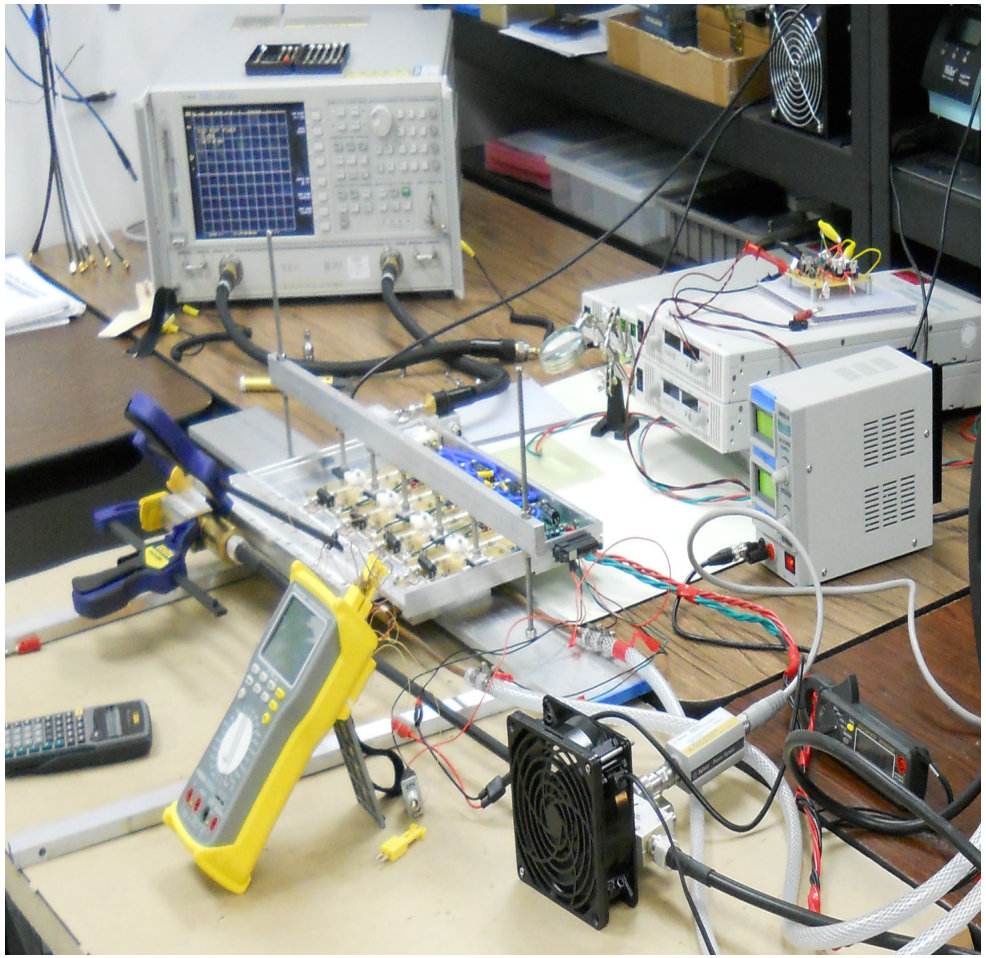


System Layout





4:1 Combiner Test



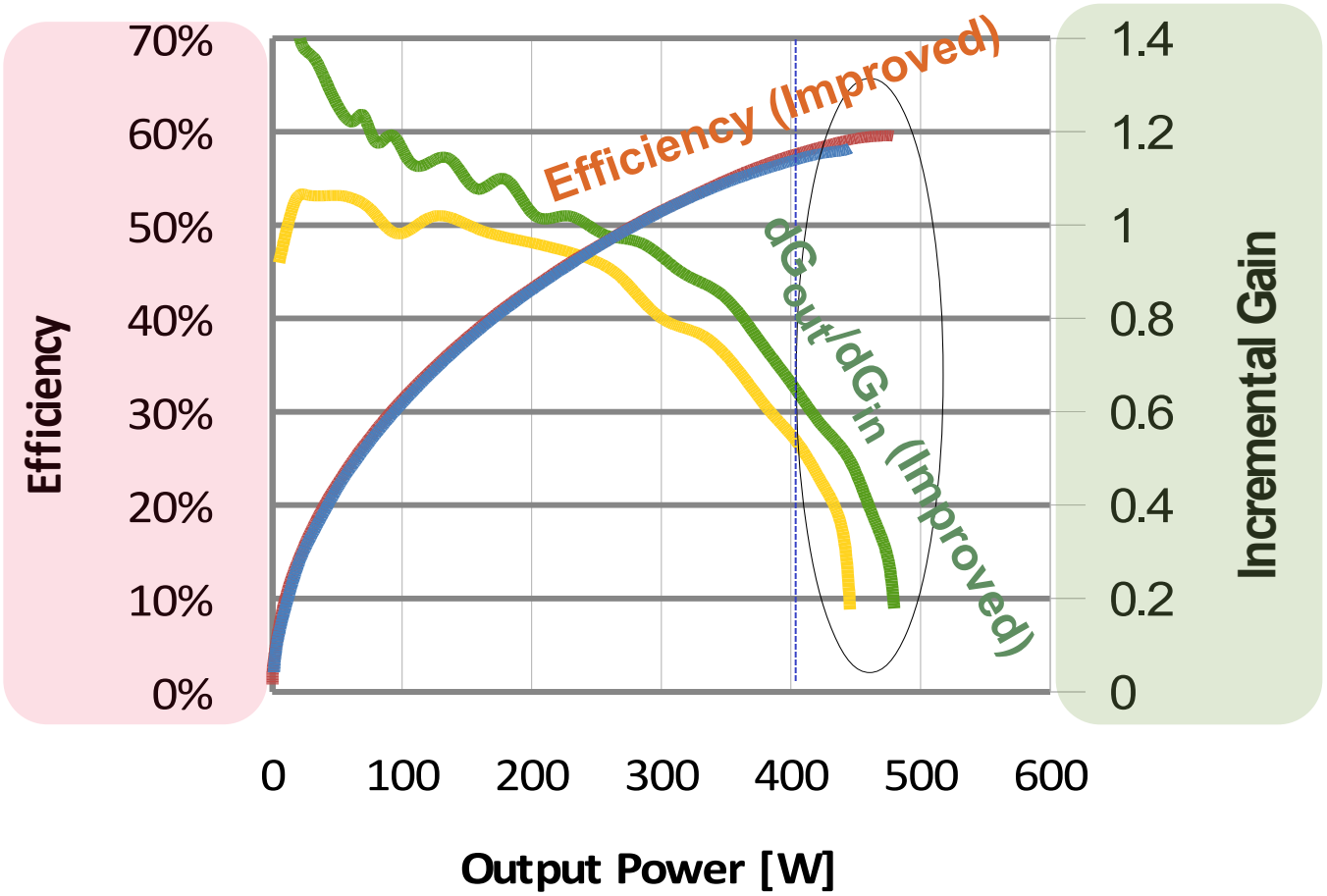
Test results indicate that the 4:1 combiner

satisfies JLAB specs at 400W

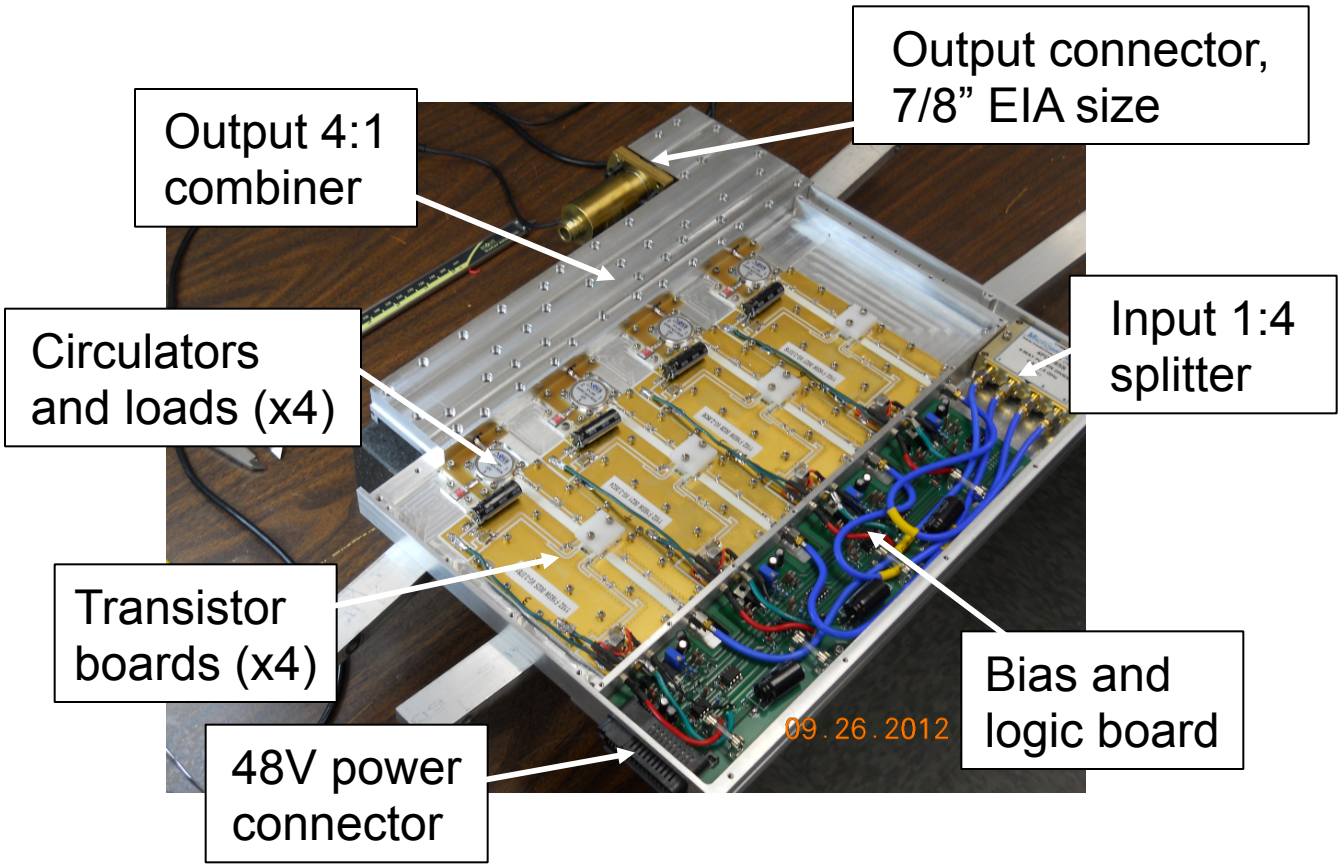
for linearity and drain efficiency >~ 60%

Improved 4:1 Combiner - Test Results

Peak power by more than 10%
Peak efficiency by 2%
dG_{out} / dG_{in} by 0.1 @ 400 W



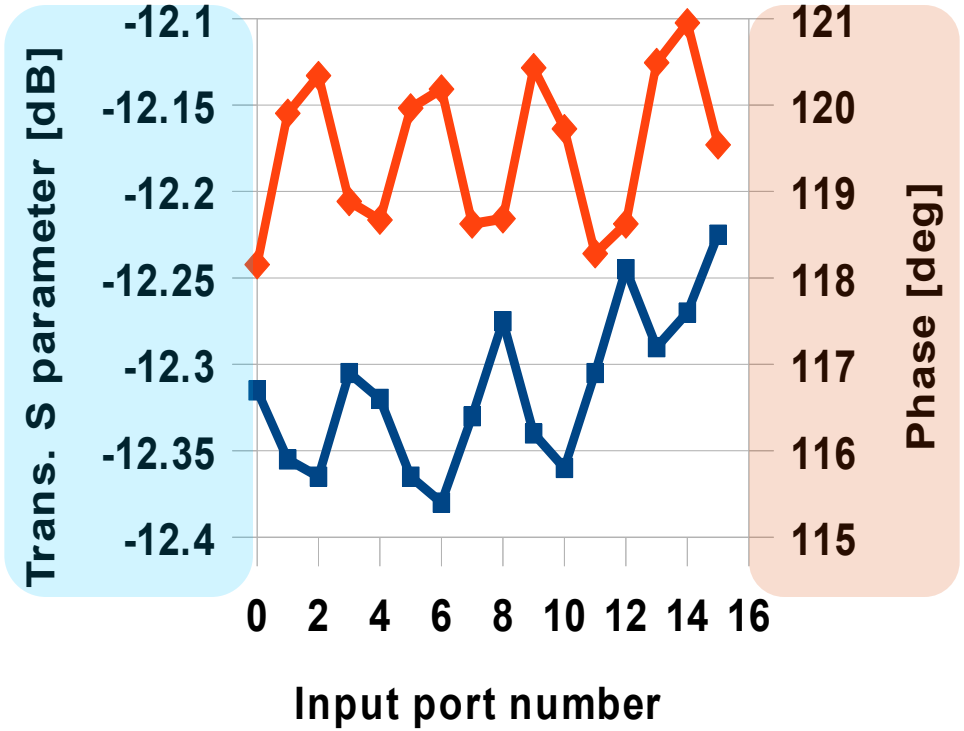
500W Module



Physical:
- 14” x 15” x 1”
- Approx 8 lbs.
- 16 units per amp

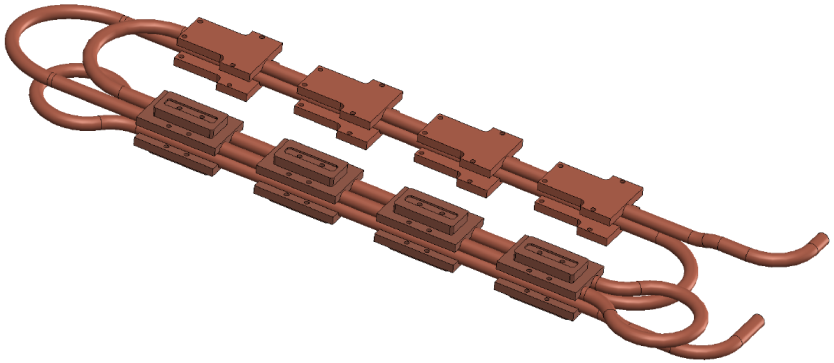
16:1 Power Combiner

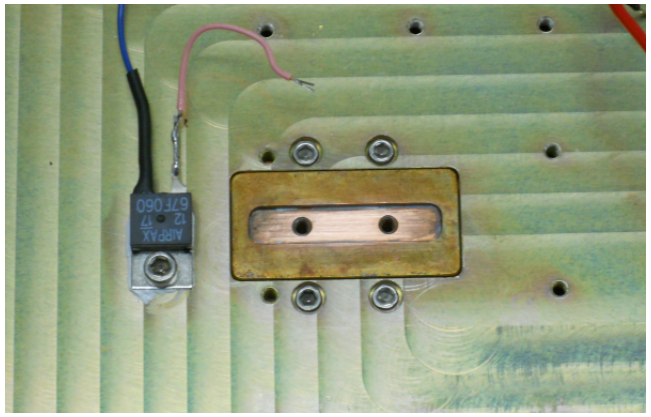
- Power imbalance: ±0.03 dB rms
- Phase imbalance: ±1 deg
- Tested to better than 20 MHz bandwidth (below -30 dB return loss)
- Insertion loss ~ 0.15 dB (without connectors)



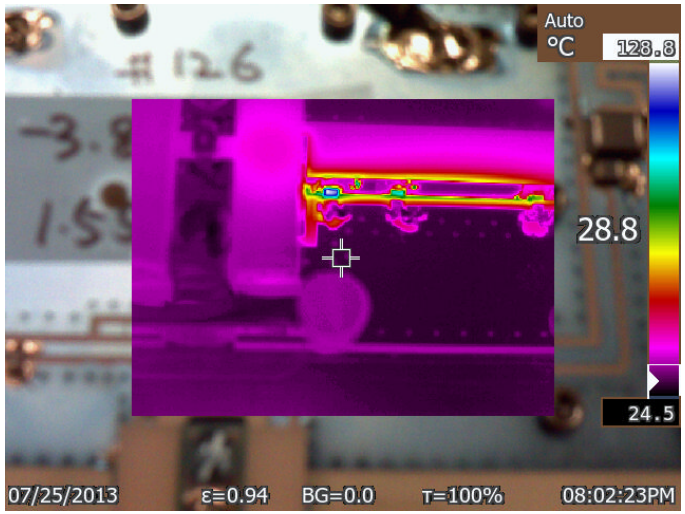
Redesigned Thermal Solution

Copper fluid cooling tube attaches directly to every transistor heat spreader.





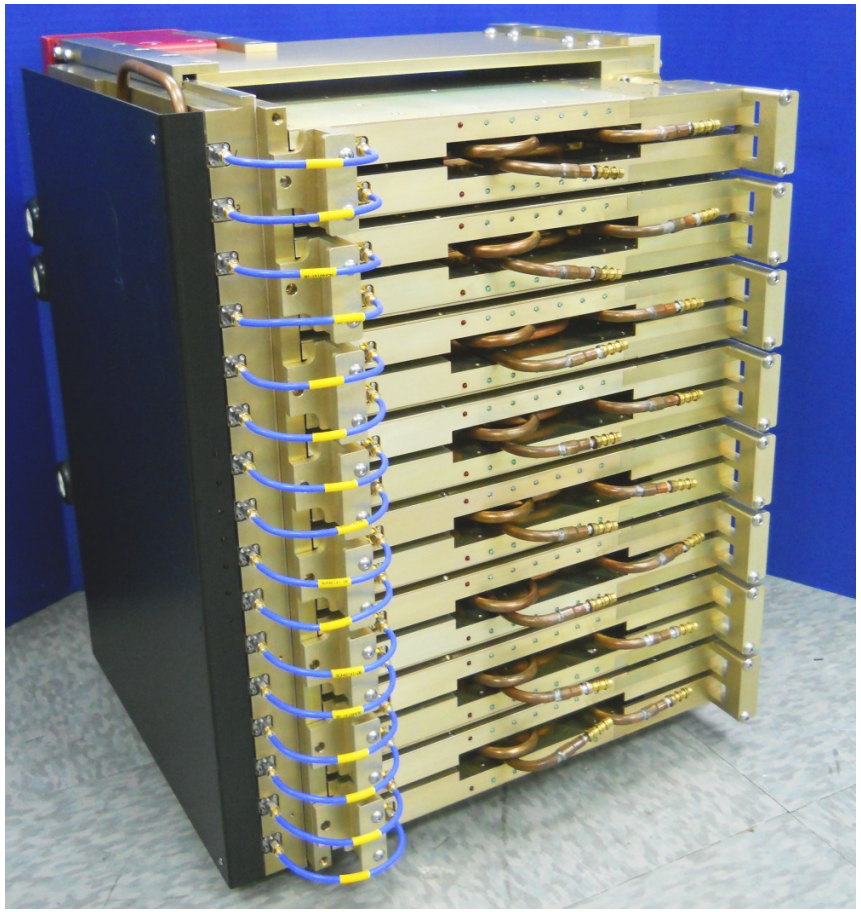
Transistor heat spreader mounted to aluminum housing.



Thermal imaging showed that output matching capacitors were getting hot. This problem has been solved:

- larger, higher Q capacitors
- thermal paste under board

Full System Test



Pre-amplifier input power: 0.2 mW

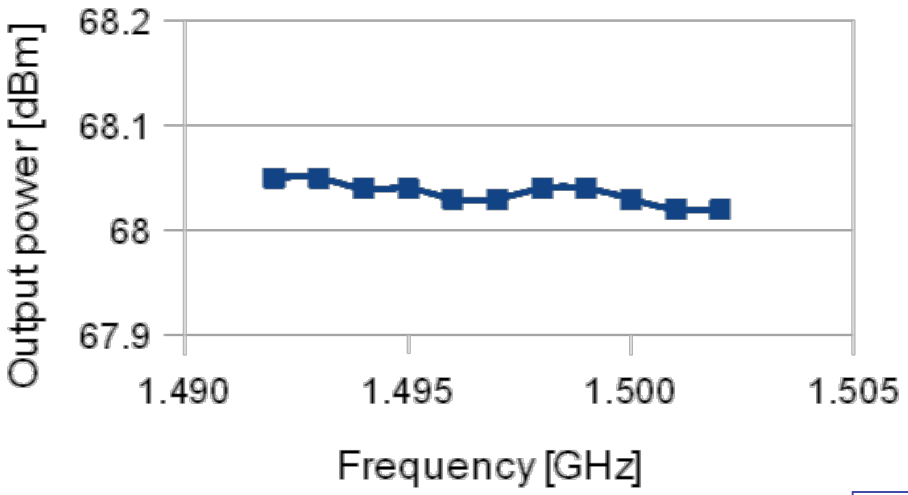
Output power: 6440 ± 15 W

Total gain: 75 dB

Power added efficiency: 54.9% ± 0.1%

Cooling water temperature: 37 ºC

Bandwidth > ± 5 MHz
(maximum frequency range tested)

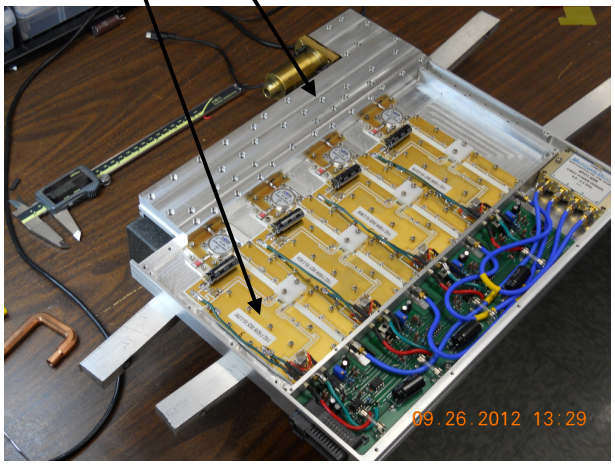


Re-Tune for 1300 MHz Operation?

1) Redesign 16:1 combiner

2) Slight change to 4:1 combiner

3) Retune transistor matching circuits.



Conclusion

Two units have been built
About to deliver amplifier to JLAB

Many commercialization opportunities

FAR-TECH

Fusion and Accelerator Research and Technology, San Diego CA

Beam Source Modeling
Plasma Technology: Modeling and Diagnostics

Linac Systems: RF source, Structure, Integration
Beam Instrumentation
Solid State Amplifiers

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