

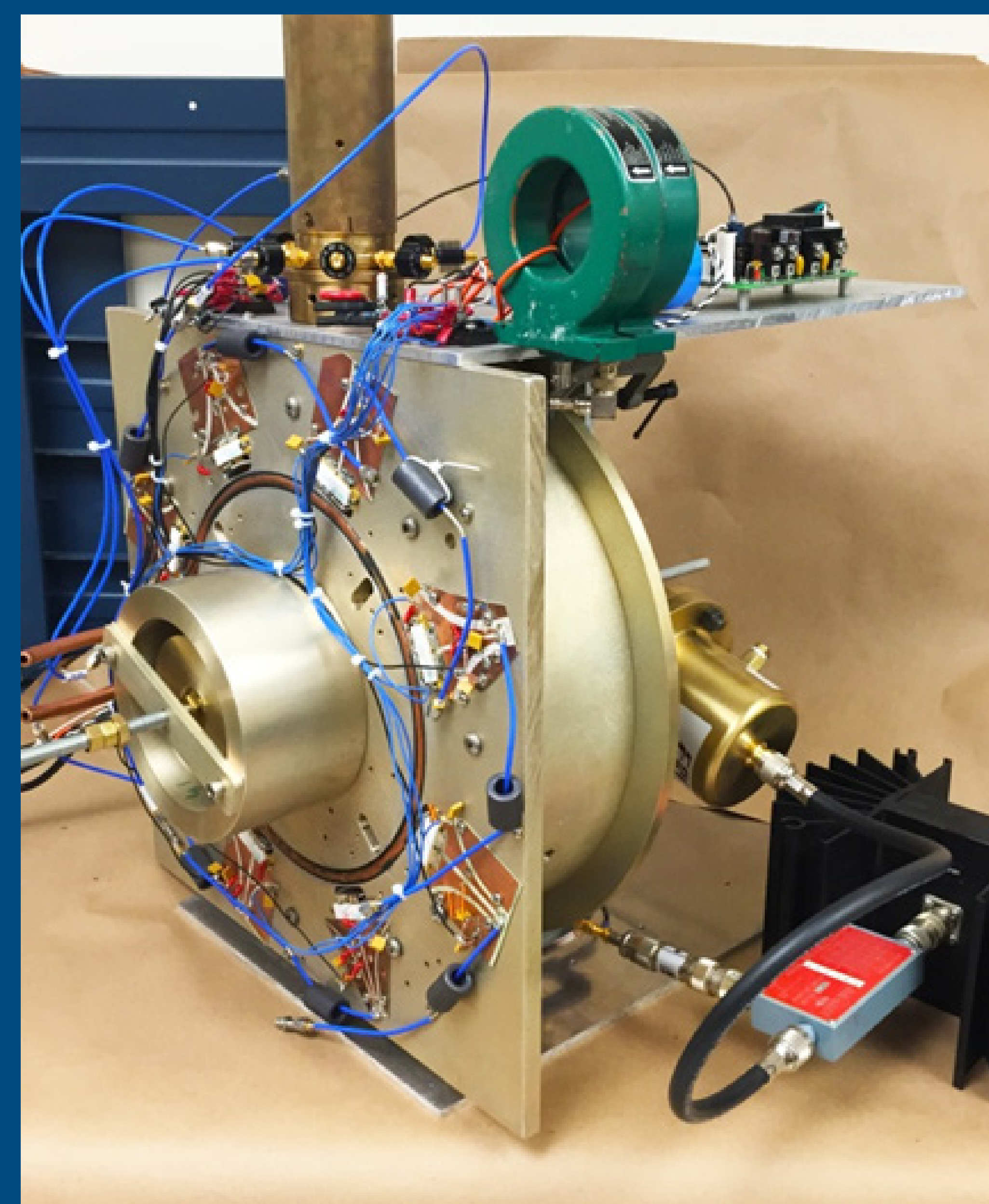
HIGH EFFICIENCY HIGH POWER RESONANT CAVITY AMPLIFIER FOR PIP-IIP

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OVERVIEW

An advanced high-power, high power density, solid state power amplifier (SSPA) was developed to replace legacy Vacuum Electron Devices (VEDs). Diversified Technologies, Inc. (DTI) developed and integrated a resonant-cavity combiner with solid state amplifiers for the Proton Improvement Plan-II (PIP-II) at Fermilab. The architecture combines the power of N-many (up to 100+) RF power transistors into a single resonant cavity that are surface-mounted and -cooled. The system is designed so that failure of individual transistors has negligible performance impact. Due to the electrical and mechanical simplicity, maintenance and logistics are simplified leading to reduced capital and operating costs.

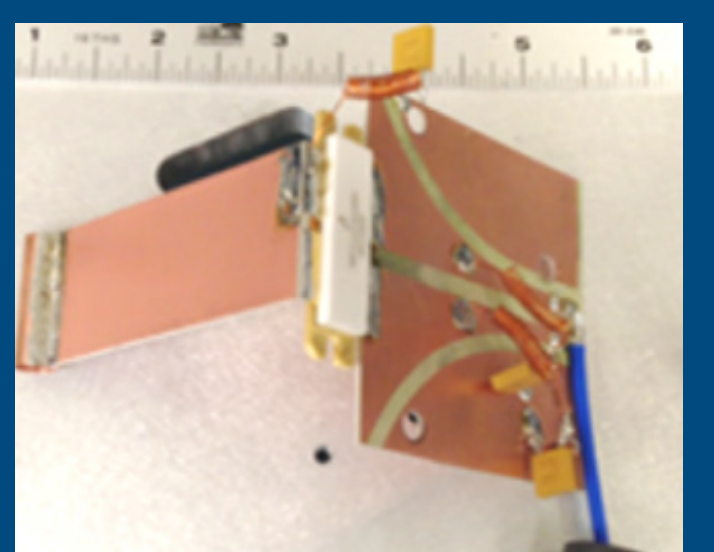
DTI demonstrated the basic feasibility of a 50-100 kW class amplifier resonant cavity combiner system at 650 MHz. A single-cavity system reached 15 kW at 66% power-added efficiency with ten of 12 slots filled on only one of two cavities faces. The system further demonstrated the expected graceful degradation; an intermittent fault occurred on one of the ten modules and the only observable effect was a reduction in output power to 13.3 kW with a slight reduction in efficiency. Combining of multiple cavities was also demonstrated at low power.



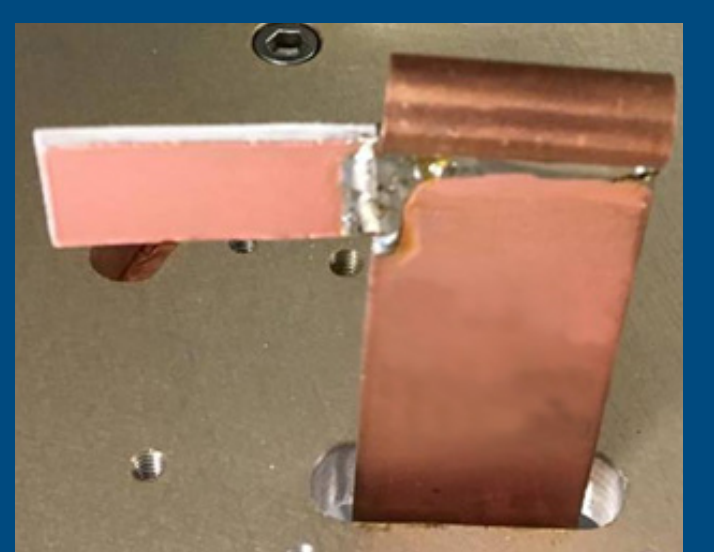
Upgraded four-transistor cavity-coupled amplifier to high efficiency (~70%) Class-E, demonstrated under Phase I.

Demonstrated 15 kW with ten devices.

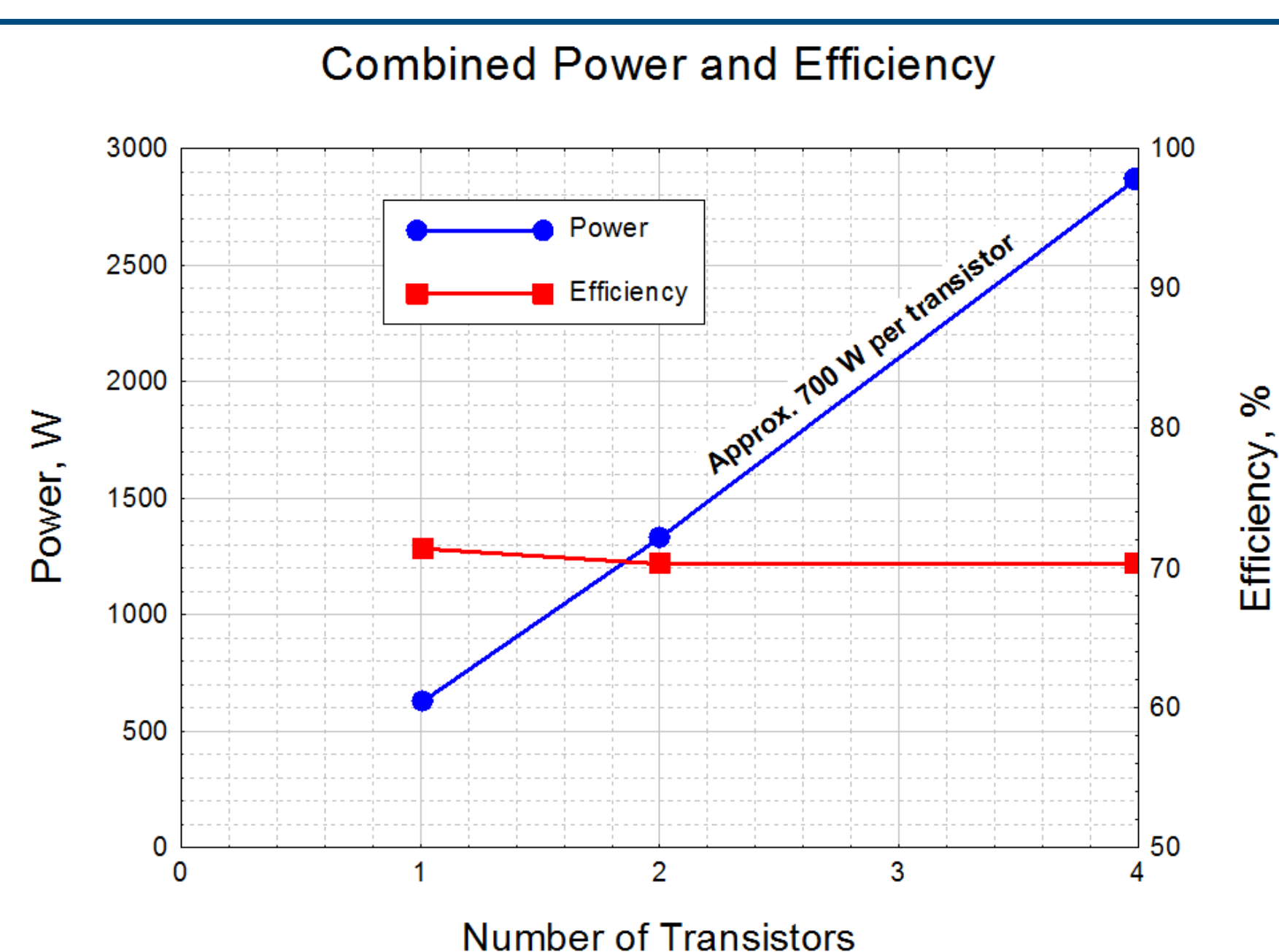
L-shaped Class-E amplifier board assembly, showing the push-pull input tapered matching network, output matching line, fusible choke, and cavity coupling loop.



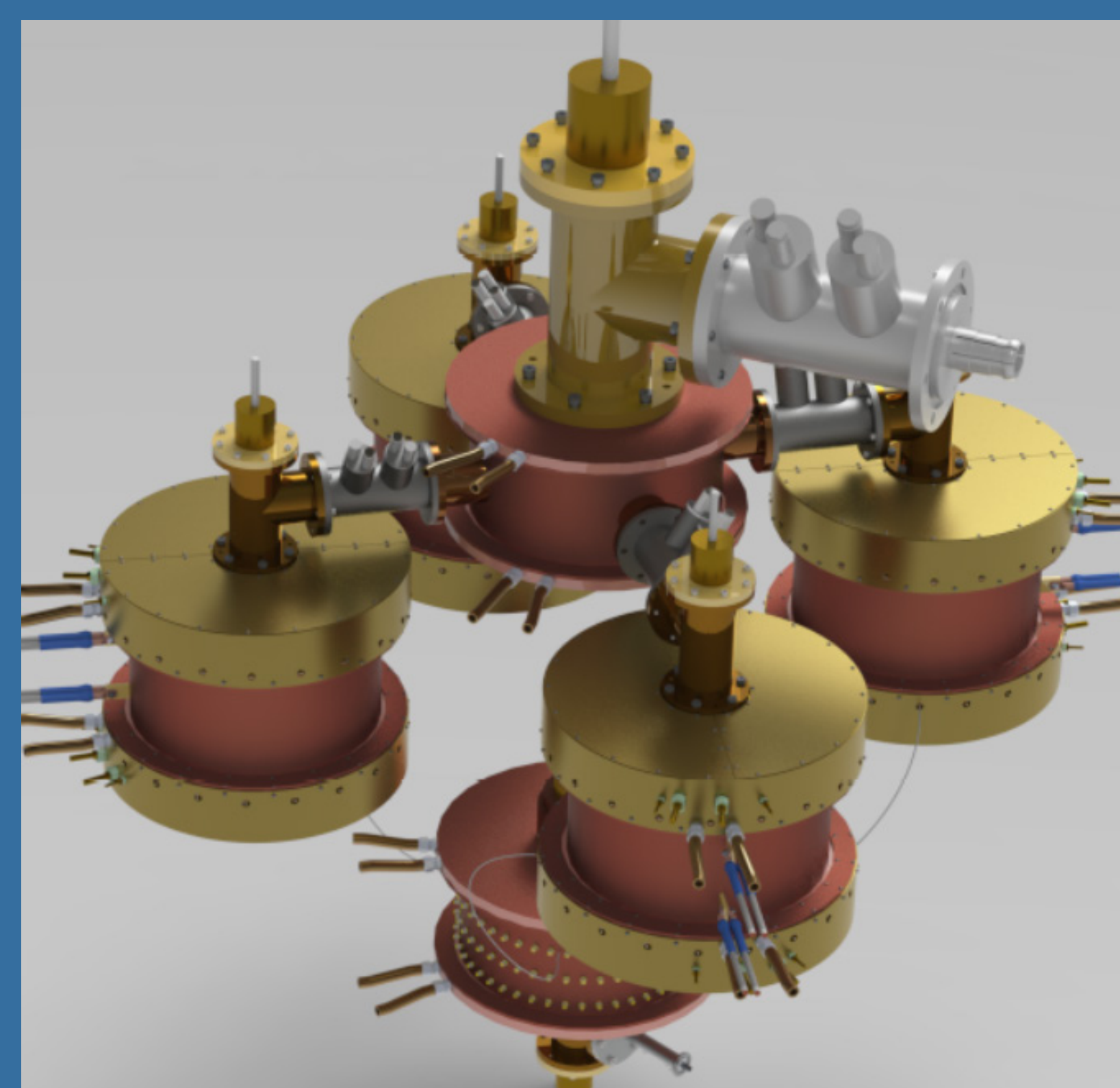
The output-coupling loop and transmission line inside the cavity. The 1/4 wave transmission line, added stub, and coupling loop provide improved "Class E Type" performance.



Project Achievements



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Conceptual layout of a high power solid state transmitter based on four DTI cavity amplifier modules combined in a passive 4:1 cavity combiner. Power level of at least 500 kW.

DESIGN DESCRIPTION

- The TM010 cavity is driven by circular arrays of loop-coupled transistors attached to both end walls.
- The output of high power transistors are impedance matched and combined in one step.
- This power is coupled out via a 3-1/8 inch 50 ohm coax with a single central E-field output-coupling probe.
- Drive signals are coupled to transistors from a similar small resonant cavity divider.
- Cooling is implemented with efficient parallel water-cooling channels in the end walls under the transistors.

KEY ATTRIBUTES OF DTI'S DESIGN

- Integrates Solid-State Power Amplifier stages into the combiner
- Practical Simplification
 - Transistor drains are coupled directly to the cavity
 - No need for multitude of circulators, cables and connectors
- Easily Scalable
 - Allows combining of a near-arbitrarily large number of transistors without a similar increase in electrical and cooling connections
- Failure in one or several transistors has negligible performance impact
- Scaling to L-Band demonstrated