LDMOS SOLID STATE RF POWER → CW/10-500MHZ

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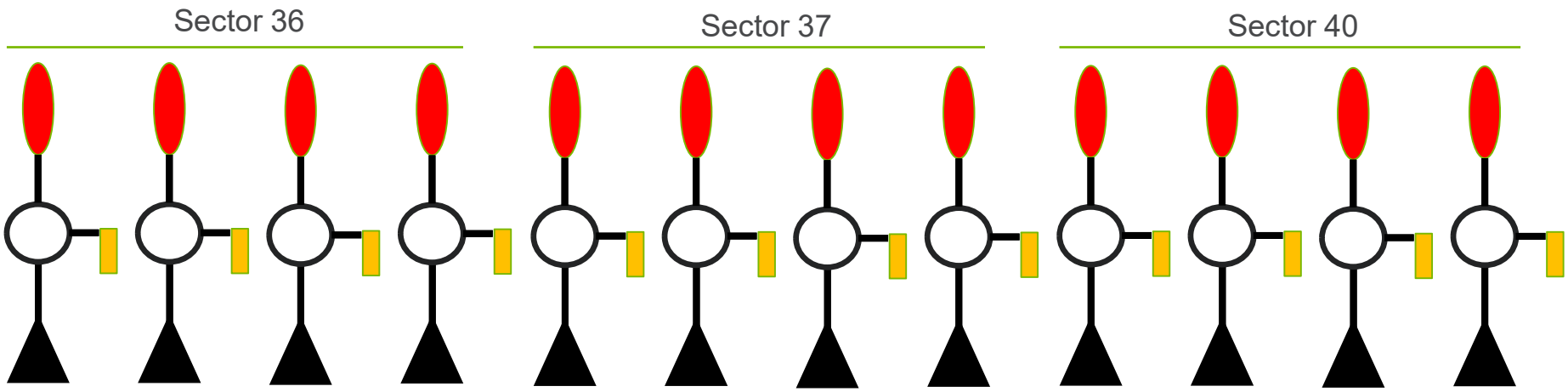
GARD ROADMAP VIRTUAL MEETING
FEBRUARY 11TH, 2026

OUTLINE

- Advanced Photon Source (APS) 350MHz Solid State RF System
- Current LDMOS SSA Developments and State of the Art
- Needs and Applications Driving Further Development
- Proposed Areas for R&D Over the Next Ten Years
- Workforce Development Outlook – Risks and Opportunities

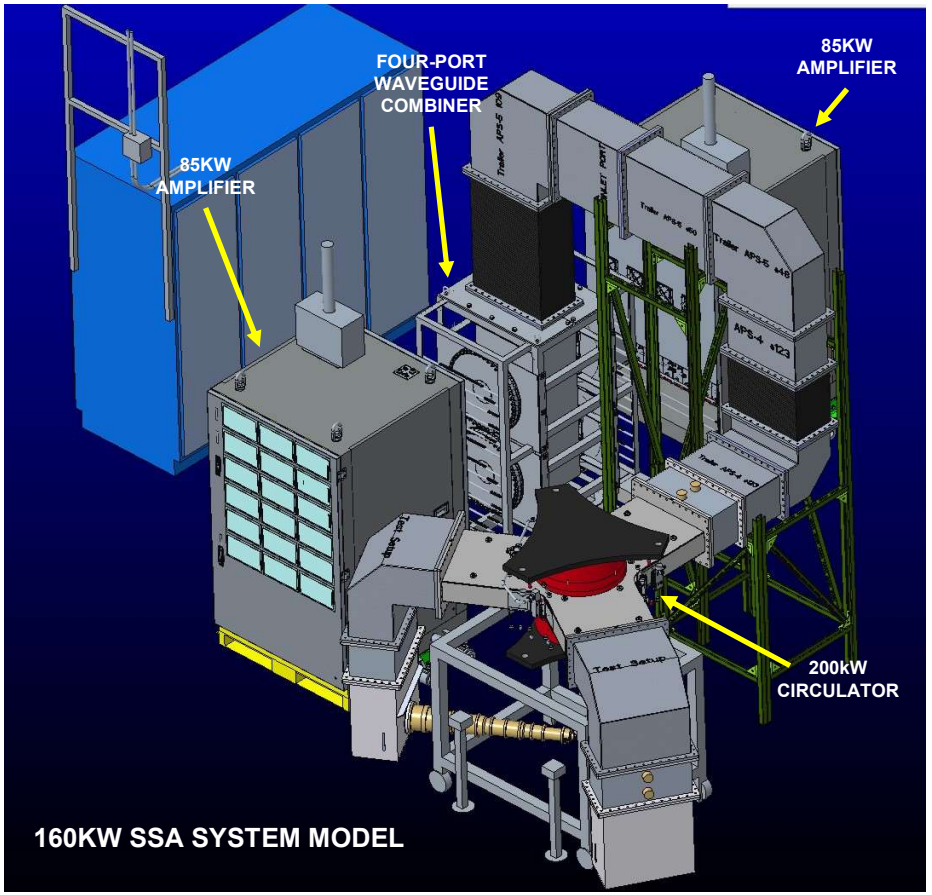
APS STORAGE RING RF SSA CONFIGURATION



- Twelve 160kW SSA systems, each driving one storage ring cavity
- Nominal rf power with full beam load is 120kW/SSA
- Each SSA configured with separate digital low-level rf and interlock systems
- Global interlock control of all systems for ACIS and MPS

160KW SSA FOR APS STORAGE RING RF

- Twelve 160kW SSA systems
- Maximum floor footprint requirement: 12’ x 16’
- Each system consists of two 85kW amplifier cabinets, a final waveguide combiner, and a remotely located PLC Control Unit
- Each 85kW Amplifier Cabinet utilizes ninety-six 1.25kW modules that feed the inputs of two 48-way radial combiners using coaxial cables
- 200kW circulator on output of each system for hardware protection
- Conservative design – 10% redundancy in both drain dc power and rf power

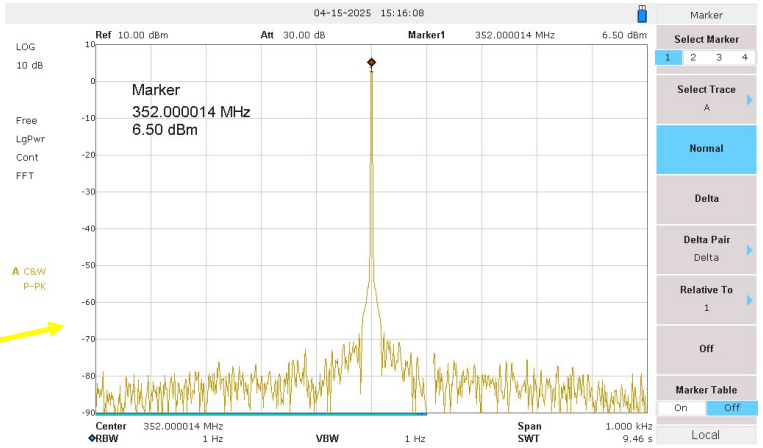


APS SSA INSTALLATION

- 192-way final combiner with coaxial inputs and WR2300 waveguide output
- *Watt-for-watt, SSA systems take up more space than vacuum tube equivalents!*
- Installation of SSA while keeping legacy rf systems operating is a significant challenge

CURRENT DEVELOPMENTS AND STATE OF THE ART

- CW rf power density at 350MHz is ≈ 1,000 watts per cubic foot with 1.25kW parts
- LDMOS is best choice for 500MHz and below – high gain, efficiency, and VSWR tolerance
- Full-power AC to RF efficiency ≈ 60-62% at output flange
- Spurious output ≈ -84dBc with no correction
- Phase variation at 10%-90% power ≈ 5°
- Adjustable drain voltage allows efficiency optimization at lower rf power operating points

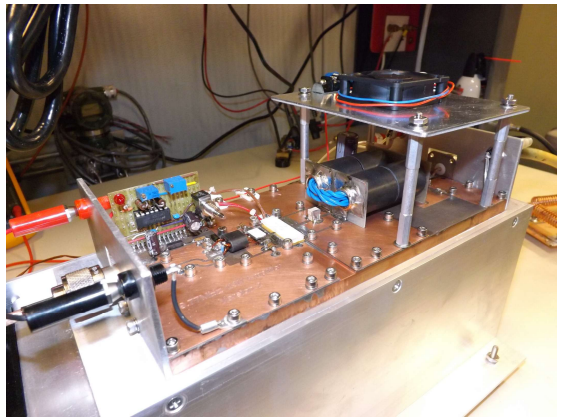


VERY LOW NOISE FLOOR AT 160kW OUTPUT

NEEDS AND APPLICATIONS DRIVING FURTHER DEVELOPMENT

- Increase power density to reduce footprint of SSA system
  → *SSA systems occupy lots of space!*

- Consider LDMOS for low frequency rf applications:



9.77MHz/300-WATT DRIVER AMPLIFIER FOR A GROUNDED-GRID TRIODE – ***running at 30 volts so air cooling is possible!***

- Owner/user serviceability is necessary
  → *Component-level troubleshooting and repair*
  → *Develop service benches to test complete modules*

PROPOSED AREAS FOR R&D OVER THE NEXT TEN YEARS

- Improved cooling strategies to allow utilization of higher-power transistors (> 1.5kW/device) and related passive parts without increasing failure rates
- New power amplifier circuit designs to reduce passive electrical parts count
- LDMOS operation at 60V-100V and related circuit designs
- New rf cable and connector designs to allow for operation at higher module power
- High reliability/efficiency drain power supply designs that provide 60-100V output

WORKFORCE DEVELOPMENT OUTLOOK – RISKS AND OPPORTUNITIES

- Special skills required for component-level troubleshooting and repair of SSA hardware – particularly replacement of transistors
- Design and build bench test setups for module-level performance testing and fault diagnosis
- Develop familiarity with SSA operating system software (PLC, PIC, etc)
- Design and build interlock systems that can protect SSA's from catastrophic damage

THANK YOU!