Summary

Two significant and long anticipated events took place in the past quarter: Director's review and Critical Decision 1 (CD-1) DOE review of the APS Upgrade project. Although, it will take some time to fully comprehend the outcomes and process all reviewers' comments and recommendations, it is evident that both reviews were successful. Along with this good news, I am sorry to say that ASD had a 120VAC shock indecent in August. This prompts me to ask you again to always think about your own safety and always lock out before you begin work. The operational statistics for the 2015 fiscal year is 137 hours of the Mean Time Between Faults and 98.9% of the Machine Availability, which is the outstanding result, only the second one to the best result ever achieved. During the reporting period the **Magnetic Devices Group** installed in Sector 32 the modified 1.8-cm period undulator and successfully completed the magnetic tuning of the prototype vertically polarizing undulator with the horizontal gap. The device meets or exceeds LCLS-II technical specifications and could possibly be used to replace the existing LCLS undulator. The undulator is now undergoing additional mechanical and environmental tests. In the other development, the prototype superconducting undulator for LCLS has been successfully tested. It also meets or exceeds required technical specifications. The **Accelerator Operations and Physics Group** played a critical role in the preparation to the APS-U reviews by performing massive simulations of MBA lattice. Other developments (also related to the APS-U) included understanding of beam accumulation limit in PAR and upgrades to the Booster correctors and BPMs. Commissioning of the new photocathode electron gun was also pursued. The **Power Systems Group** completed the past run with a 99.3% of power supply availability and an MTBF of 854 hours. There were two beam losses attributed to the power supplies: one resulting from a failure of the converter for the quadrupole power supply and one from malfunctioning of the GESPAC power supply. The group also worked on the upgrade to the Booster correctors and continued a heavy involvement in the APS-U project. The **RF Group** completed past run with a total rf system downtime of 0.088%. A high-current beam study was conducted on the last day of the run, and the rf systems maintained a storage ring beam current of 150-mA with no issues. The shutdown activities included a long list of routine maintenance and replacement of 200-kW rf loads at Sector 38/Hybrid #1, Sector 37/Hybrid #1, and Sector 37/Hybrid #3 locations. Non-routine shutdown activities included replacement of the Sector 40/cavity #2 input coupler due to a water leak, performing rf measurements on both PAR rf cavities, re-positioning a waveguide section at port #3 of the RF3 circulator, performing a visual inspection of the RF3 circulator interior, replacement of 200kW rf loads at Sector 38/Hybrid #1, Sector 37/Hybrid #1, and Sector 37/Hybrid #3 locations, replacement of the thyratron crowbar trigger at RF1 with a solid-state equivalent, replacement of the 350-MHz RF Test Stand klystron monitoring PLC, and installation and painting of kick panels on the RF1-RF5 matching transformer housing bases to address corrosion damage. The report from the **Diagnostics Group** will be included in the next quarterly report.

More Detailed Group Reports

The Accelerator and Operations Group

Many group members were involved in the Director's and CD-1 reviews. Specific activities included (a) complex simulations of the electron beam dynamics affected by the rf cavity higher-order modes, feedback and a high-harmonic cavity, (b) designing of a high-beta insertion to MBA lattice, (c) simulation of particle loss distribution and designing of the collimation system. AOP continued to study high charge injector operation and demonstrated accumulation of 24-nC in the PAR and extraction of 10-nC. The blow-up of the vertical beam size in the PAR was observed at high currents and it was understood that the likely reason for that is the accumulation of ions. AOP also coordinated the upgrade of the Booster corrector control hardware that resulted in reduction of the corrector ramp update time from 25 seconds to 4 seconds enabling a more efficient orbit correction (see also Power Systems Group section). Among other news, the commissioning of the LCLS-type photo-cathode RF gun had been continued. After rebuilding of the drive laser heads, the laser pulse energy significantly increased enabling achieving of the 110-pC electron bunch that was sent through first three accelerating structures of the APS linac.

The Power Systems Group

Power systems group members constructed a mobile power supply unit for the magnet test and measurement (see Fig. 1). The unit is capable to supply a DC current up to 200 A with a long term stability of a few parts per million. The unit also contains a precision current measurement system that includes a DC current transducer (DCCT), a temperature-controlled burden resistor, and an 8 ½ digital meter to measure the power supply current with better than a few parts per million resolution. The unit was used for the very first L-bend dipole measurement in MM1 and now is being used in Building 314 for other magnet measurement. Many group members were involved in the Director's and CD-1 reviews.

Fig. 1. A 200 A mobile power supply unit.

As discussed in the AOP group section, Booster operation was significantly improved with the upgrade of the GESPAC controlled arbitrary function generator (AFG) and slow monitoring hardware with new fast AFG and analog to digital (ADC) cards from Highland Technology. An adapter card was also designed and installed in 79 correctors to replace the old digital to analog (DAC) card and to receive the ramping references from the Highland Technology AFG.

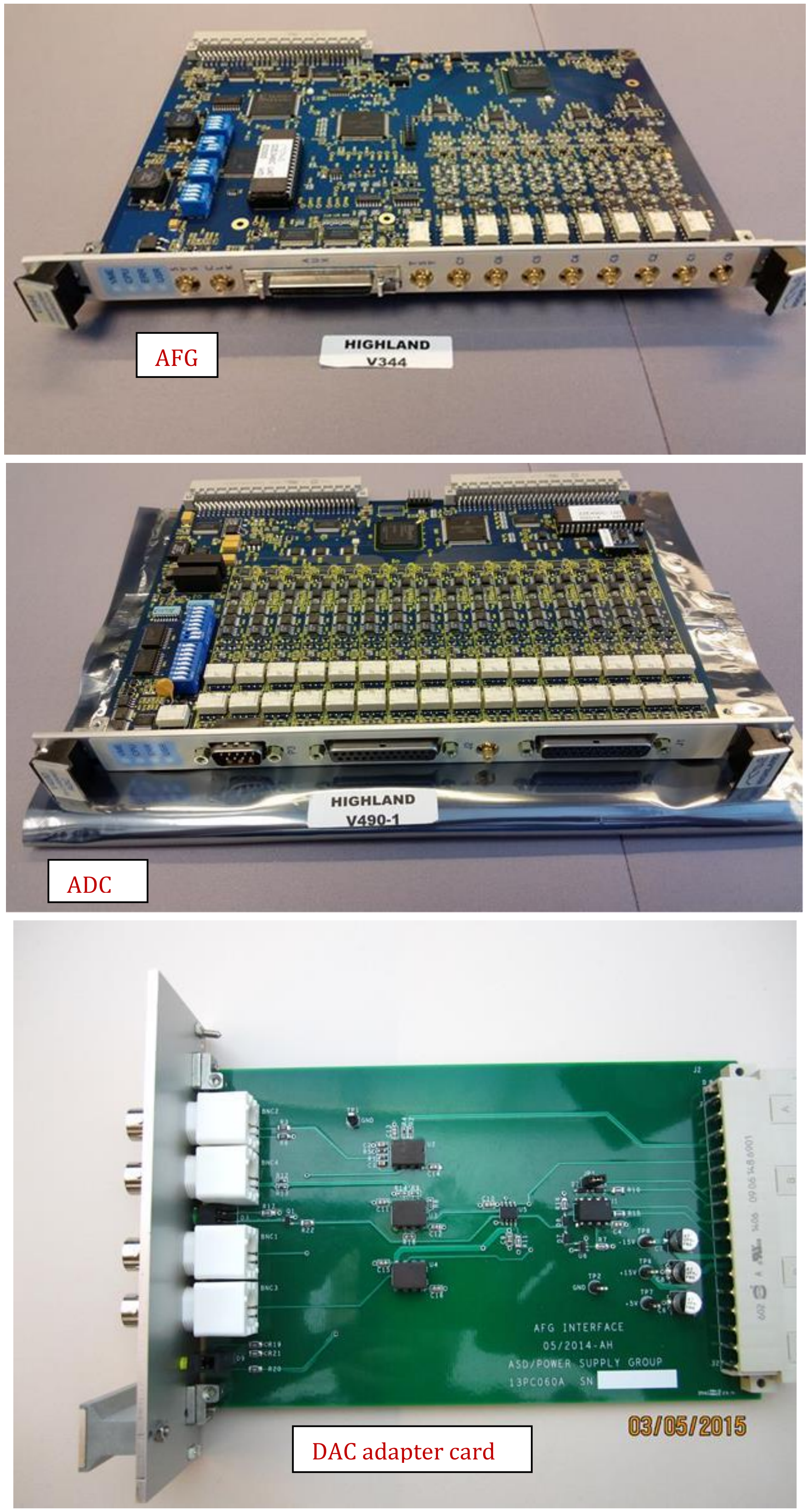


Fig. 2. AFG and ADC cards from Highland Technology and the DAC adapter card

The RF Group

On September 9th, the Sector 40/cavity #2 input coupler (s/n ANL-21) was replaced due to the discovery of a slow water leak from one of the coupler body water pipes over the Labor Day weekend (see Fig. 3). The coupler was replaced with a new spare coupler, ANL-18. The root cause of the water leak on coupler ANL-21 has not been determined, but it was noted that the water pipe was not welded to the coupler body as is the case on other couplers (see Fig. 4). An inspection of all input couplers on the Booster and Storage Ring rf cavities revealed that twelve of the sixteen storage ring couplers had welded body water pipes, but none of the booster couplers were welded. Coupler ANL-21 will be inspected for other defects. If none are found, an attempt will be made to weld the body water pipes and salvage the coupler.

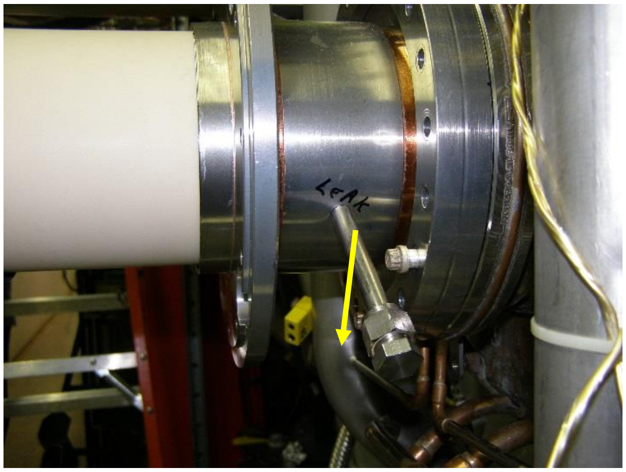


Fig. 3: Location of water leak from the un-welded body water pipe on the Sector 40/Cavity #2 input coupler.

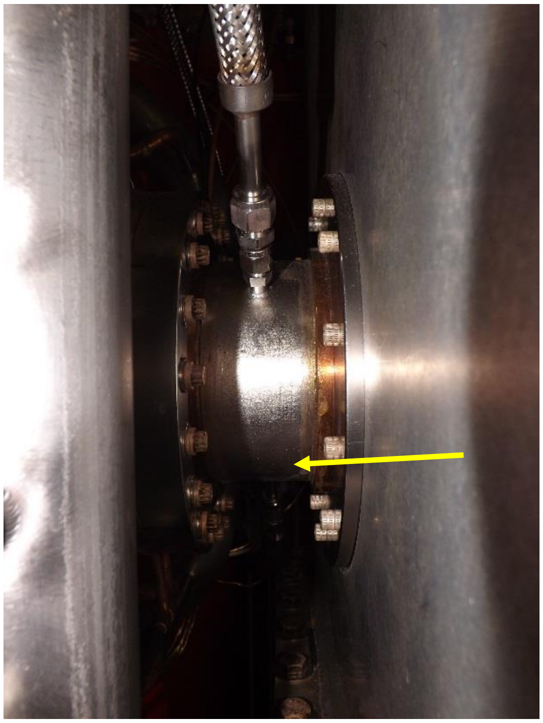


Fig. 4: Welded body water pipe on the Sector 40/Cavity #4 input coupler.

On August 26th, a test was performed to verify Booster rf system operation at a frequency 130kHz higher than present operating conditions what could be useful for the APS-U. The main 352-MHz source frequency was increased in 10 kHz steps to 352.064MHz, and various rf system parameters were monitored at each step. Outside of some very slight outgassing in the rf cavities caused by tuner movement as the source frequency was changed, the system operated normally. The klystron output power increased by approximately 4kW at 352.034MHz.

On September 2nd, the interior of the RF3 circulator was visually inspected through an open waveguide flange at port #3 (see Fig. 5). Nothing abnormal was noted, and the interior of the circulator was clean and free of debris. Photos were taken and archived for future reference.

New booster tuner ANL-BT-02 (see Fig. 6) was successfully conditioned to 100 kW in the RF Test Stand. Coupler ANL-BT-01 has been installed in the test stand cavity and will be conditioned to 100 kW as soon as operation of the RF Test Stand resumes coming out of the maintenance shutdown.

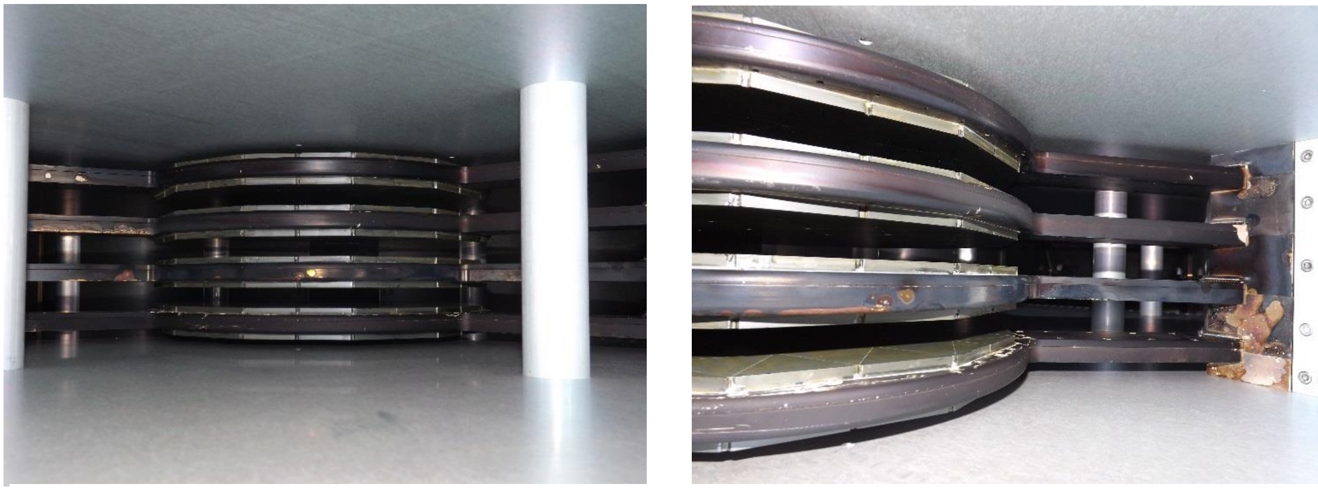


Fig. 5: Interior view of the RF3 circulator, looking in from the port #3 waveguide flange.

Fig. 6: New Booster tuners ANL-BT-01 and ANL-BT-02.

Operation of the test stand was disrupted over this quarter due to several hardware problems that degraded the test stand cavity vacuum. The first indication of a vacuum problem was noted during the conditioning of the first new booster tuner, when the cavity vacuum would remain in the high E-9 range with rf power off, nearly a decade higher than the normal zero-power pressure of the cavity. Numerous leak checks on the cavity and vacuum system failed to detect a leak to atmosphere, and RGA tests did not indicate contamination. The test stand cavity ion pump was suspect due to age, and it was replaced with a spare. The cavity base pressure then recovered to normal levels, and operation of the test stand was resumed. However, the base pressure of the cavity became abnormally high again, and an investigation indicated that a pinhole leak had developed in the ceramic of the input coupler, ANL-28 (see Fig. 7). The coupler was replaced with a new green coupler that will be conditioned to full power as soon as possible after the maintenance shutdown ends.

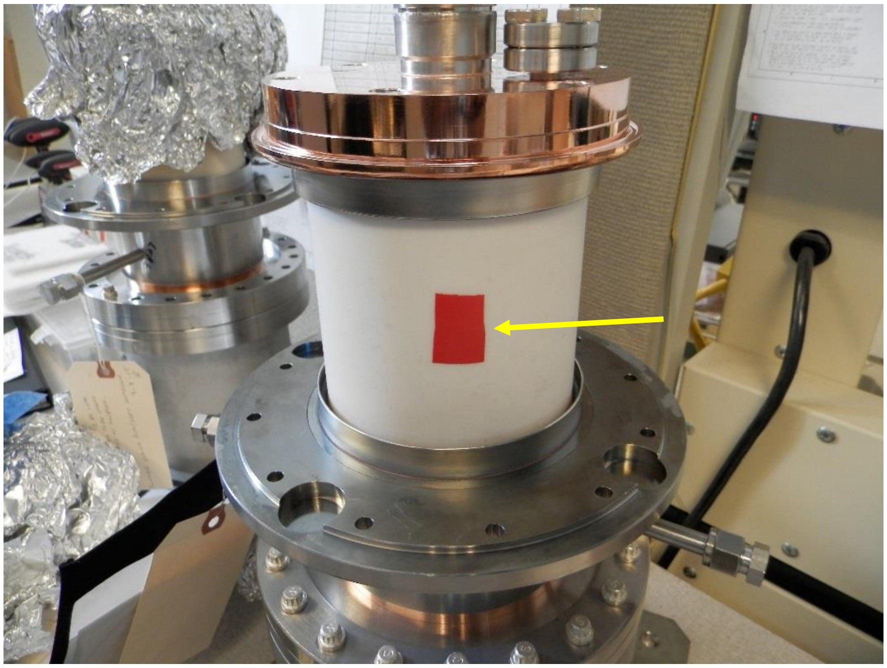


Fig. 7: Coupler ANL-28 after removal from the RF Test Stand cavity. The arrow indicates tape marking the general area of the pinhole leak.

Further progress has been made in development of solid state amplifier designs for both 352-MHz and 9.77-MHz, the work supported by the LDRD. After modifications were made to the output circuit board design, the first prototype 352-MHz, 2-kW amplifier achieved 2,177 watts output power in pulsed mode (200-µsec, 500-Hz) at a drain voltage of 60 volts (see Figs. 8 and 9). Figure 10 shows the rf gain of the prototype amplifier at various rf output levels. A new output-side circuit board including these modifications was designed, and the prototype amplifier was re-assembled with the new board. The 2-kW pulsed output performance was successfully repeated with the new output board. Testing will now transition to cw output power conditions.

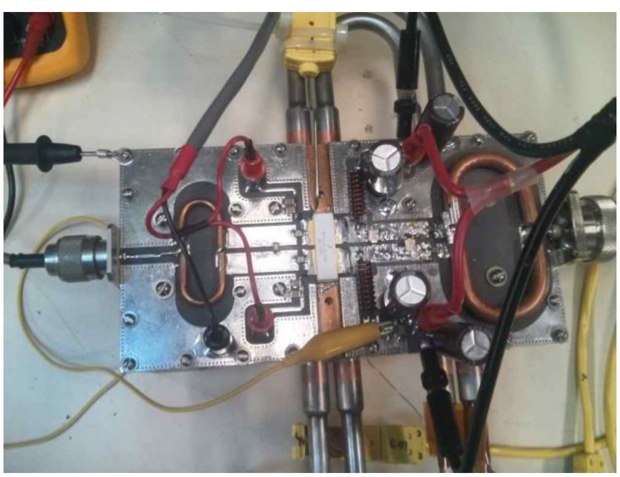


Fig. 8: Prototype 352-MHz, 2-kW amplifier on test bench

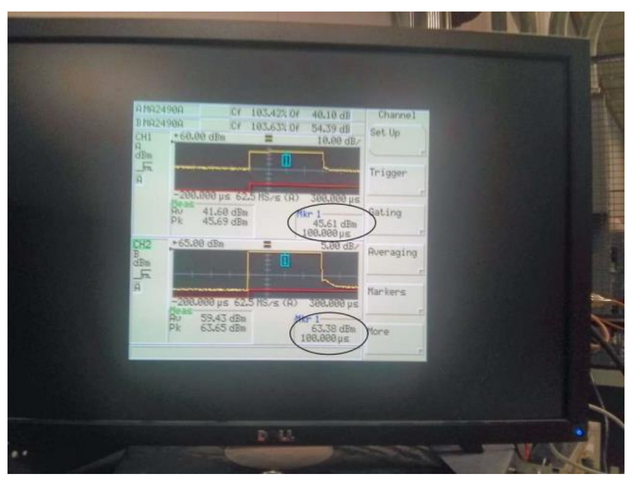


Fig. 9: RF power meter display indicating 2,177 watts peak output power.

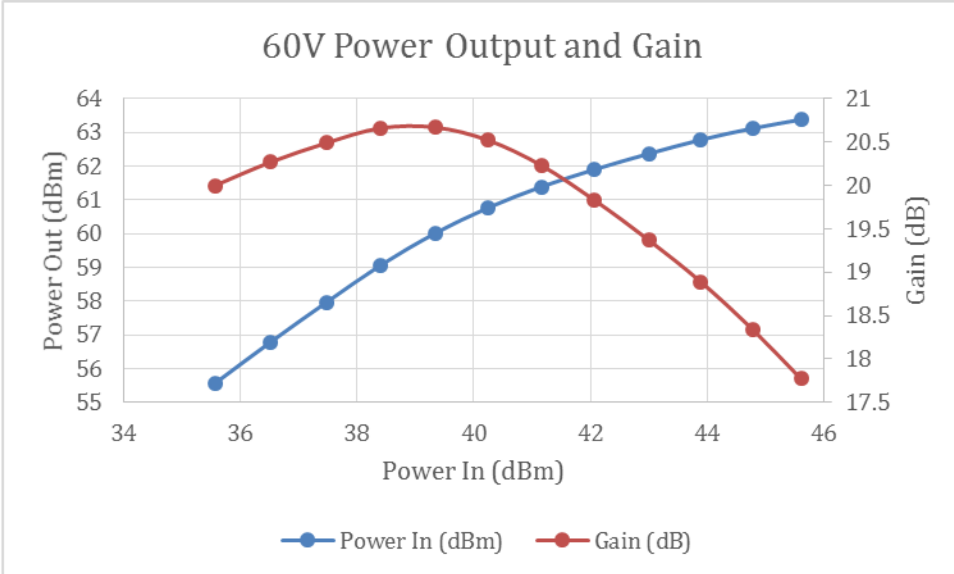
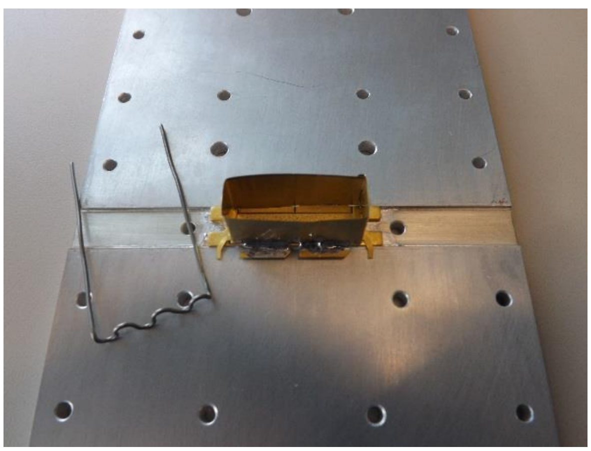
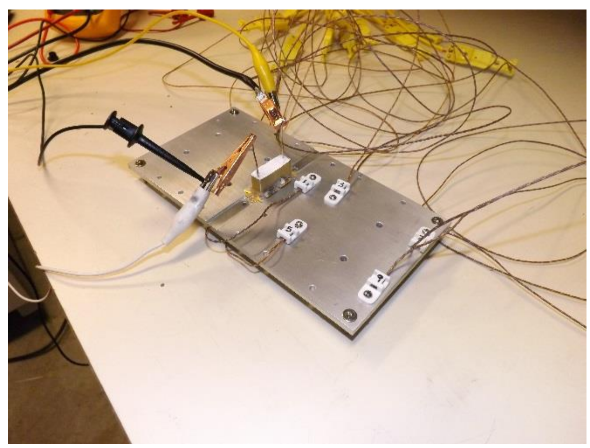


Fig. 10. RF output, input, and gain data.

Evaluation of thermal performance of the Euclid heat spreader, designed to fit the cold-plate bolt pattern, was started (see Fig. 11). A resistance heating wire was potted into the blank transistor flange that was soldered to the heat spreader by Euclid personnel. DC power was then applied to the resistance heating wire in an attempt to simulate the power dissipation footprint of an actual transistor device.





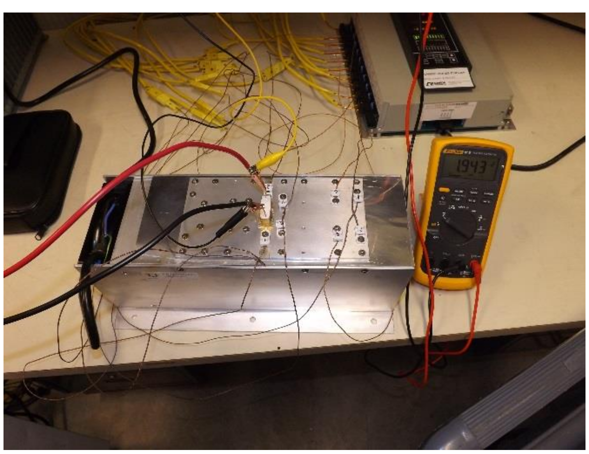


Fig. 11. <u>Top left</u>, resistance heater wire before potting into blank transistor flange. <u>Top right</u>, thermal testing on bare heat spreader. <u>Bottom left</u>, heat spreader thermally bonded to a heat sink.

Work has begun on the conceptual design for a 6-input 352-MHz, 12-kW cavity combiner that will be used as the output combiner in a 12-kW cw solid state amplifier system. Simulation rendering of the cavity is shown in Fig. 12. The cavity will be fitted with a waveguide transition output, and will utilize plunger tuners to achieve and maintain resonance.

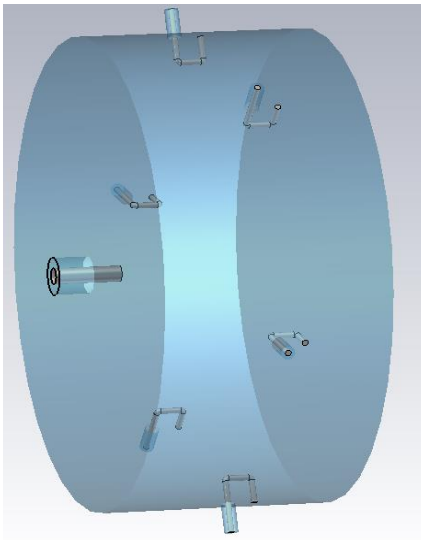


Fig. 12. Simulation rendering of the 6-input, 352-MHz/12kW cavity combiner, showing input coupling loops and output coupling post.

The design of a new 9.77-MHz driver amplifier that will replace the existing obsolete amplifiers presently in use in the Fundamental PAR rf systems was completed (see Fig. 13). The second prototype was successfully tested in the PAR rf system under beam conditions this summer. Protective covers and a 24-volt power supply box were added to provide an rf shield for the amplifier circuit board and dc power to the cooling fans and gate bias regulator. Four additional amplifiers are under construction, and will be used to replace the existing driver amplifiers during FY16.

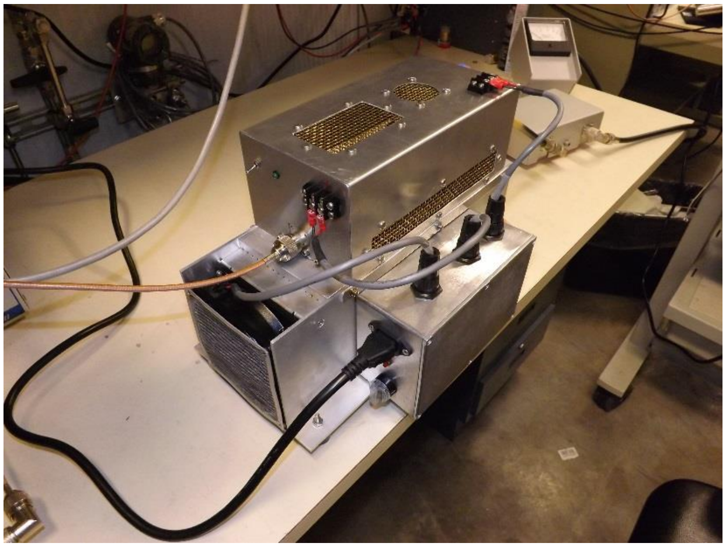


Fig. 13. 9.77MHz prototype amplifier #2 fitted with shield cover and 24-volt dc power supply box.

Work has also begun on the design of new 117.3-MHz driver amplifiers for the Harmonic PAR rf system. New amplifiers are necessary to replace the existing drivers, which use an obsolete field effect transistor that is very difficult to obtain.

Significant progress in coating of high-temperature superconducting MgB_2 thin film on bare 2" polished copper discs using High-Pressure Chemical Vapor Deposition (HPCVD) (Fig. 14) has been made within the framework of the LDRD for new SRF materials. Initial rf characterization of these samples clearly showed superconducting transition temperature at 39K of MgB_2 but with lesser than the expected quality factor mainly due to some surface contaminates during deposition and sample handling. In addition, work on the conformal deposition process using plasma-assisted atomic layer deposition got underway. It received its final chemical safety review and deposition on 5" wafers is underway.

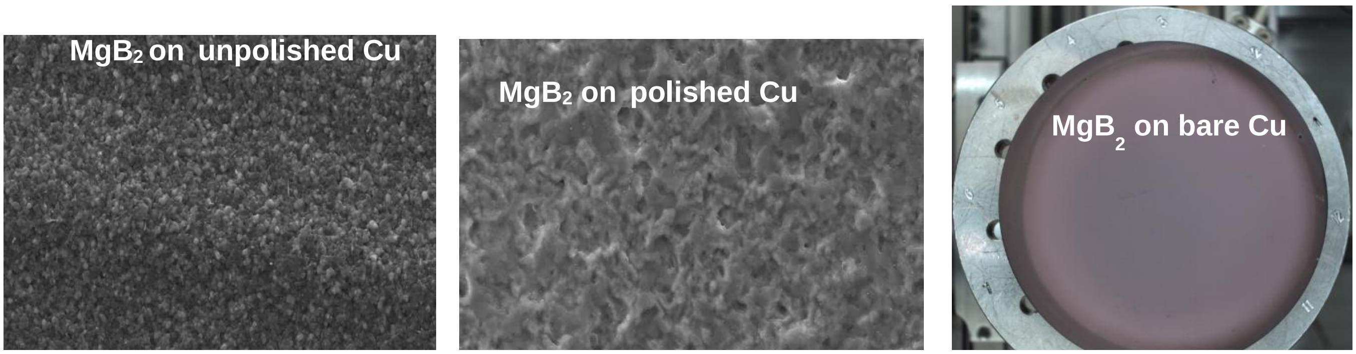


Fig. 14: SEM images of unpolished/polished bare copper coated with MgB2. The images show of polished Cu show smaller grains compared to the large grains seen on unpolished copper. A uniform and dense MgB2 growth on bare copper is also observed.

Work is progressing to convert the Multi-Purpose Amplifier (MPA) to L-band operation by fitting it with a CPI L-band IOT. The MPA will be utilized to provide a nominal 20-kW cw of rf power for testing the Bunch-Lengthening Harmonic Cavity coupler. The MPA is being re-assembled in Building 400A for initial L-band testing (see Fig. 15). The L-band WR-650 waveguide system and isolator have been assembled, and construction of the water system to supply the isolator and rf load water circuits from the main amplifier water manifold is underway. The repaired top cover for the L-band IOT was received from CPI, and the 50kW L-band rf load was received from Altronic Research.

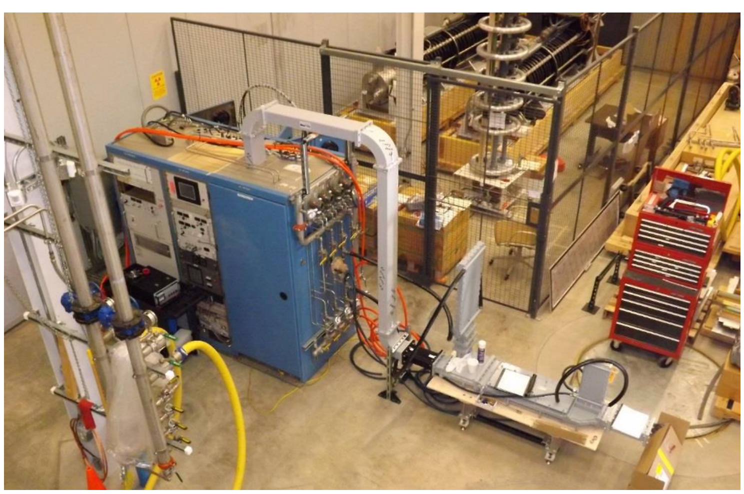


Fig. 15. Multi-Purpose Amplifier assembly in Building 400A, showing the WR-650 waveguide system and L-band isolator.