

Summary

At the time of writing (June 29, 2015) the operational statistics is 579 hours of the Mean Time Between Faults and 99.8% of the Machine Availability, which is the outstanding result. During the shutdown in May the **Diagnostics Group** installed a prototype next-generation X-ray Beam Position Monitor (XBPM) in the 24 ID First Optical Enclosure. This XBPM employs Compton scattering of x-rays off diamond blades to define beam offset. The **Magnetic Devices Group** replaced the prototype revolver undulator at Sector 35 by the new revolver undulator and installed the SCU1 at Sector 1 with the repaired vacuum chamber. The measurements of the photon flux produced by SCU1 at 82 keV photon energy show 4-times improvements comparing to the Undulator A. Other activities in MD group include characterization of the prototype M1 magnet for MBA lattice and assembly, measurement and tuning of a novel undulator with a spring loaded compensation of the magnetic force. This undulator has a gap adjustable in the horizontal plane which makes it most useful for Free-Electron Lasers and future diffraction limited light sources. A development of new prototype superconducting undulator for FELs in a collaboration with LBNL and SLAC is ongoing. The magnetic structure built in ANL has passed all cryogenic tests in the vertical cryostat and the assembly of device in the horizontal cryostat has started. The **Accelerator Operations and Physics Group** has successfully commissioned new superconducting undulator SCU1. All required measurements and tests were performed quickly, the related software was commissioned, and the undulator was timely released for operations. The **Power Systems Group** completed the Run 2015-1 with a 99.20% of power supply availability and a 384 hour MTBF. There were 4 beam losses attributed to the power supplies. Two of the losses were suspected from the same power supply, S3A:V3, but it was not possible to reproduce the glitch condition on the test stand. The majority of the 0.8% down time was due to the rf Gun 2 thyatron failure that happened at the beginning of the run and took 8.4 hours to troubleshoot and repair. The **RF Group** completed Run 2015-1 with a total rf system downtime of 0.1%. 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 130 mA with no issues other than the sudden loss of mod-anode regulation at RF4. A waveguide switch to RF1 was performed, and the high-current run was completed without any other problems. The shutdown activities consisted of routine system maintenance, analysis and repair of the RF4 mod-anode tank, and repair of corrosion on the 13.2 kV matching transformer bases for RF3 and RF5, located outside Building 420 (see Fig.1). Severe rust damage to SG-R3, the 13.2 kV switchgear dedicated to feeding primary power to the storage ring and booster rf systems, was also noted (see Fig.2).



Fig. 1: Corrosion addressed with sealant paint on the RF3 matching transformer base.

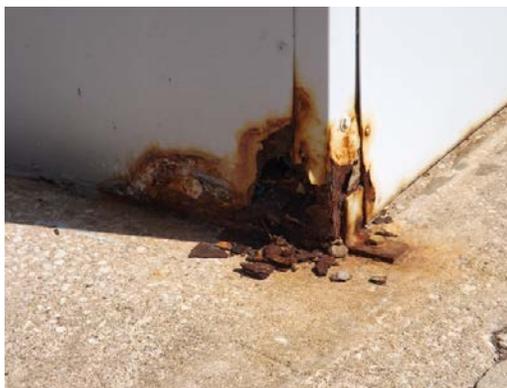


Fig. 2: Severe corrosion on the SG-R3 switchgear enclosure outside Building 420.

Detailed Group Reports

The Accelerator and Operations Group

The Accelerator Operations and Physics (AOP) group has successfully commissioned new superconducting undulator SCU1 that was installed in sector 1. The commissioning went smoothly, all required measurements and tests were performed quickly, the related software was commissioned, and the undulator was released for operations right on the first day of the run. It was found that the new undulator does not quench during beam dumps unlike the previously installed SCU0. The difference in behavior is determined by the locations of the undulators (in Sectors 1 and 6) relative to the main beam loss location in Sector 4 defined by a narrow aperture vacuum chamber. The work is ongoing on protection of the SCU0 undulator from the quenching during beam dumps. A beam abort system design involving an abort kicker was developed by the AOP. The abort kicker was installed during May shutdown. Initial tests of the beam abort system with low-current beams were successful. The operation with high current beams will begin after the radiation safety of the beam abort will be established.

The operation this user run will always be with the Reduced Horizontal Beamsize (RHB) lattice, which was requested by the RHB user in Sector 32. The hybrid mode was improved by increasing the current in the main bunch from 16 mA to 20 mA. This was made possible due to the improved nonlinear beam dynamics achieved through sophisticated sextupole optimization. Among other operations related developments, the under-performing RG2 gun was replaced with another gun, which now supports the operation with lower heater current and less linac bunches. As part of that work, a beam tune-up procedure was developed that would allow for easier gun exchange in the future. Also, after the vacuum chamber exchange in ID4, the beam-based measurements confirmed that the old chamber (the one that was installed during May shutdown) has larger gap and lower impedance compared to the chamber that was there during the previous user run.

In the work related to APS Upgrade, the R&D continued on high-charge injector operation. A timing card that allows for 1 Hz injector operation was installed and tested. Commissioning of the new BSP-100 BPMs started in the Booster, which should allow for better orbit control during the Booster ramp. Investigation of the ion effects in PAR is also ongoing. A software supporting magnetic measurements of the APS-U prototype magnets was written by the AOP and tested during the measurements of the first prototype magnet M1. The work on other physics issues is continuing.

The Diagnostic Group

The next generation XBPM (named Compton XBPM) shown in Fig. 3 will be a lower cost alternative to the GRID XBPM system installed in the front-ends in sectors 27 and 35. The Compton XBPM is optimized for lower heat load canted undulator front-ends. The design is based on Compton scattering of hard X-rays off diamond blades. A set of diode detectors records the flux and difference over sum is computed in downstream electronics to obtain position information. The Compton XBPM was successfully reviewed last year and as part of the ESAC review recently completed this month.

Figure 4 shows results of the first test with beam carried out in 24 ID during machine studies. The figure shows very good undulator hard X-ray photon to bending magnet background signal ratio up to 1000 to 1 as the gap is varied. Figure 3 shows a nearly gap independent calibration factor. These data were taken by moving the Compton XBPM prototype assembly using a motor controller. The gap dependent offset evident in Fig. 5 is presently being investigated and is not clearly understood at this point. Fig. 6 shows very good position sensitivity where the Compton XBPM assembly was moved using the motion controller by 80 microns. The difference over sum ratio varied by more than 12 units. Some issues found in these initial tests were that one diamond

blade was malfunctioning and lower signal intensity was measured compared to simulation. Results so far are promising and testing will continue into the summer and fall runs.

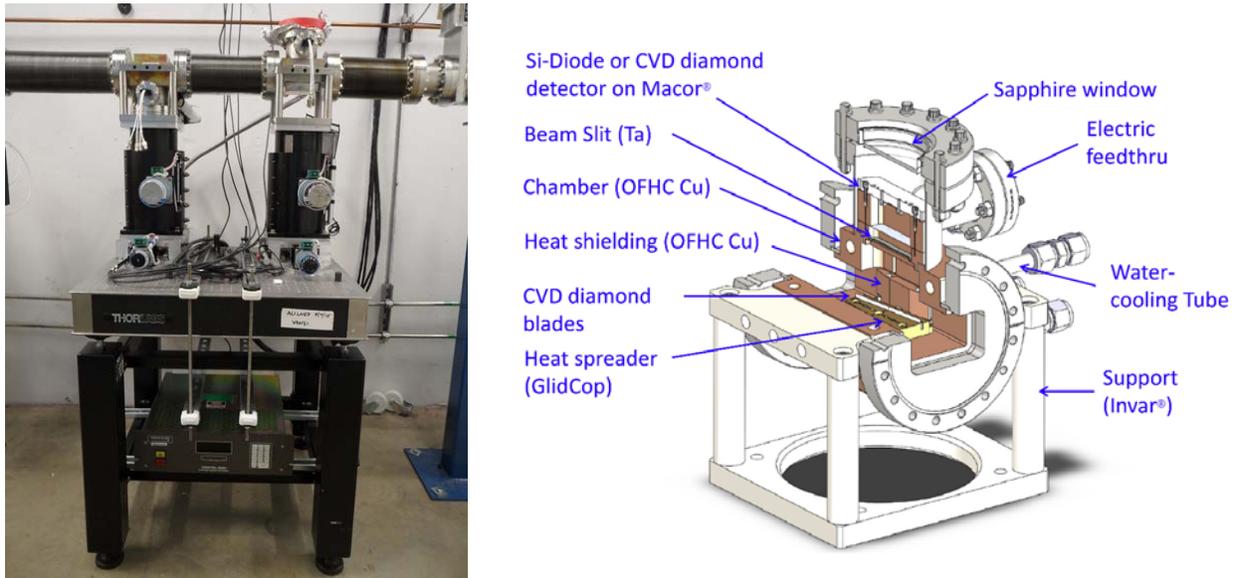


Fig. 3. Compton XBPM installed (left) and cutout view (right).

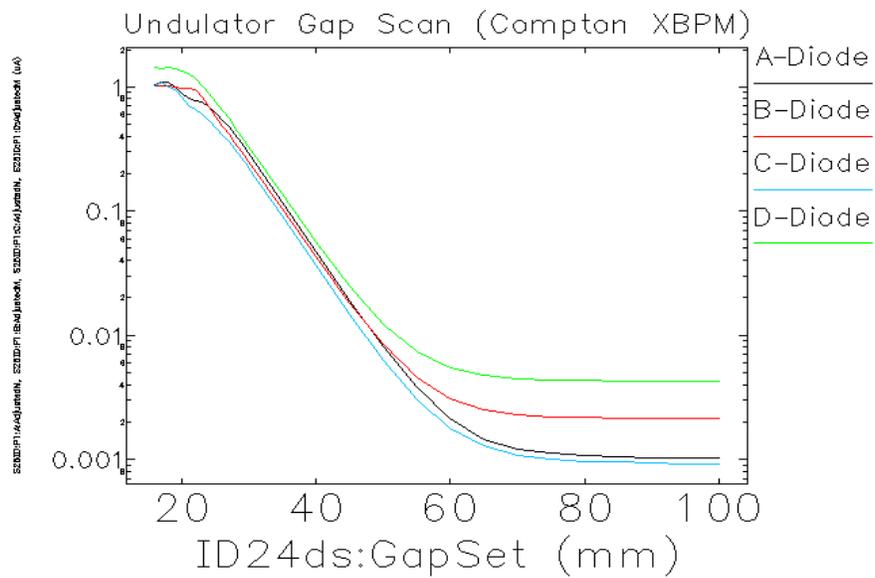


Fig. 4. Blade signals of the Compton XBPM as function ID gap shows very high signal to background ratio.

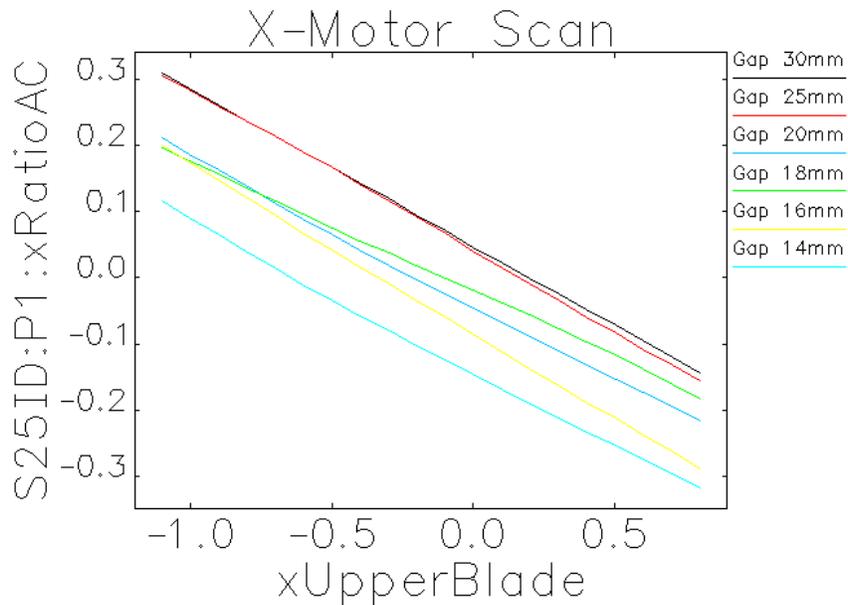


Fig. 5. Horizontal scan of XBPM stage shows nearly gap-independent calibration factor. The gap-dependent offset is being investigated.

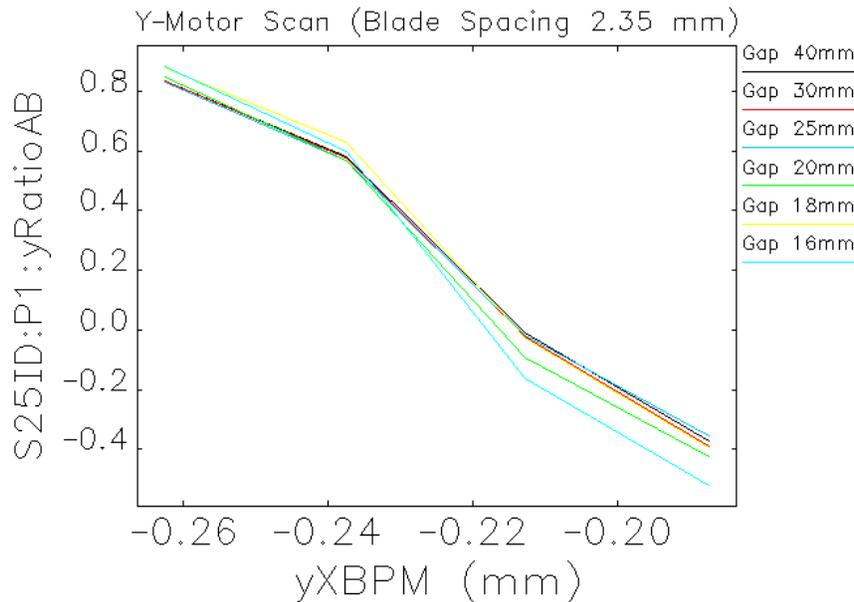


Fig. 6. Vertical scan of XBPM stage shows extremely sensitive position dependence which is almost independent of undulator gaps.

The Power Systems Group

Each of the three power supply systems for the electron gun heaters for RF Gun1, RF Gun2, and RF gun in the Injector Test Stand had unique configurations in the power supply components, the databases, scaling factors, and etc., because the systems were developed at different times. The uniqueness of each system made the operations and maintenance more difficult than it had to be. In the shutdown, all the power supply components and the database of the three systems were

updated to the same design. This improvement has simplified the operations and reduced the required maintenance.

Several developments related to the group activity in the APS-U project took place. A class-D switching mode power amplifier circuit, SA12 from APEX, was prototyped for the fast corrector power supplies. The result was that this amplifier had too much switching and conduction losses that the built-in thermal protection would stop the operation when the current reached beyond 10 A. APEX has proposed an improved version, SA12/4, that is expected to reduce the losses significantly. The proposal is being evaluated.

A contract has been awarded to Lawrence Berkeley Laboratory to collaborate with the APS-U accelerator team to develop and refine high-speed data communication protocols and ancillary software in support of the fast orbit feedback control R&D effort. The fast communication is based on the LBNL's FPGA-fabric-based commercial-IP-less GigE UDP implementation.

The RF Group

To improve the energy match between the booster beam at the extraction and the storage ring beam, a modification was made to the RF5/Booster ramp waveform to increase the ramp length from 253 milliseconds to 256 milliseconds. Modifications were made to EPICS displays, process variables, and on-screen trigger timing adjustments in order to accurately read the peak rf power at the end of the 256 millisecond ramp.

Production of the first two new booster cavity tuners built in-house has been completed. New booster tuners ANL-BT-01 and ANL-BT-02 (see Figs. 7 and 8) were assembled, and conditioning of ANL-BT-01 at 352-MHz test stand is underway, reaching 40 kW average power as of June 18th. Also a new storage ring coupler ANL-27 was conditioned to full power.



Fig. 7. Booster tuner ANL-BT-01 prior to installation in rf test stand cavity for conditioning.

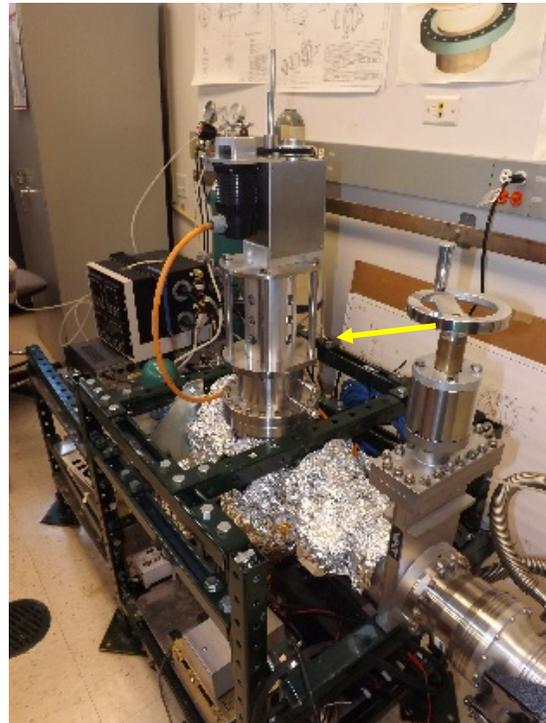


Fig. 8. Booster tuner ANL-BT-02 stored in vacuum chamber, awaiting installation in test stand cavity.

A prototype 200 kW coaxial rf load, designed and built by Calabazas Creek Research (CCR) under an SBIR program, was installed in the test stand for testing and evaluation. Photos of the load are shown in Figs. 9 and 10. The load consists of an internal 50 Ω resistor that is cooled by flowing de-ionized water. The goal of the load design was to develop a surface preparation process that would resist the aggressive nature of highly-purified de-ionized water, which is known to cause erosion of the internal rf electrical contact surfaces on loads of similar design over time. The test plan included validation of load operation at the full input power of 200 kW cw over a period of eight hours, followed by approximately two years of exposure to flowing de-ionized water coolant with no rf power applied. At the end of this period, the load would be disassembled and examined for evidence of contact surface erosion.



Fig. 9. The CCR 200kW rf load as received.



Fig. 10. The CCR load installation at the test stand, just prior to attachment to the waveguide transition.

The load was first measured on a network analyzer for a reference impedance measurement, followed by attachment to the test stand waveguide system for the rf power test. RF power was applied to the load and slowly increased to approximately 60 kW cw until a routine rf field measurement indicated a 0.23 mW/sq.-cm electric field leak from the second body flange of the load (see Fig. 11). At this point, rf power testing was stopped and CCR was notified of the rf leak. While awaiting further instructions from CCR, the load developed a water leak through a weep hole after approximately one week of exposure to cooling water flow (see Fig. 12).

CCR requested that we return the load to them for analysis. It was removed from the test stand and shipped back to CCR on 6/4/15.

Further progress has been made in development of solid state amplifier designs for both 352MHz and 9.77MHz.



Fig. 11. RF field leak detected at second load body flange.



Fig. 12. Water leak from weep hole in load body.

The first carrier/cold-plate assembly for the 352-MHz/2kW amplifier development effort was received from ANL shops (see Fig. 13). This assembly will be used for cooling the first prototype 2 kW amplifier.

The first heat spreader designed to fit the cold-plate bolt pattern was delivered (see Fig. 14). Euclid personnel soldered a blank transistor flange to the heat spreader to evaluate the ability to solder components to the Euclid device. This heat spreader will be used to assess the thermal performance of the Euclid design by artificially heating the blank transistor flange with a resistance heater to simulate the power dissipation footprint of an actual transistor device. Temperature measurements on the Euclid heat spreader will be used to evaluate thermal performance.



Fig. 13. The first carrier/cold-plate assembly.

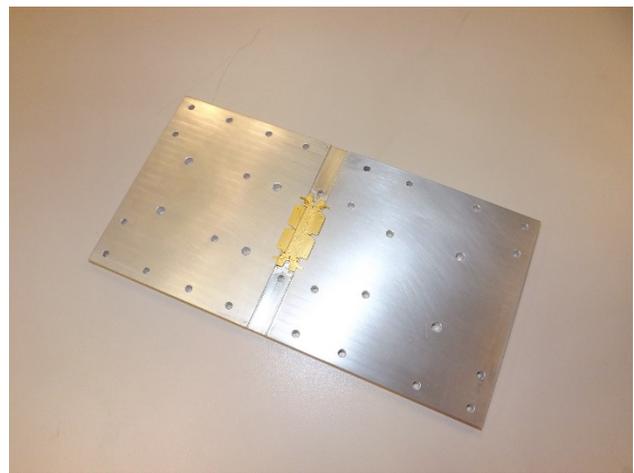


Fig. 14. The first Euclid heat spreader with blank transistor flange attached by soldering.

Construction of the first prototype 352-MHz/2-kW amplifier was completed (see Fig. 15). The amplifier was first tested in dc-only mode (see Fig. 16) to get temperature data that will be used to validate the thermal model of the carrier/cold-plate assembly. RF testing of the prototype amplifier is presently underway.

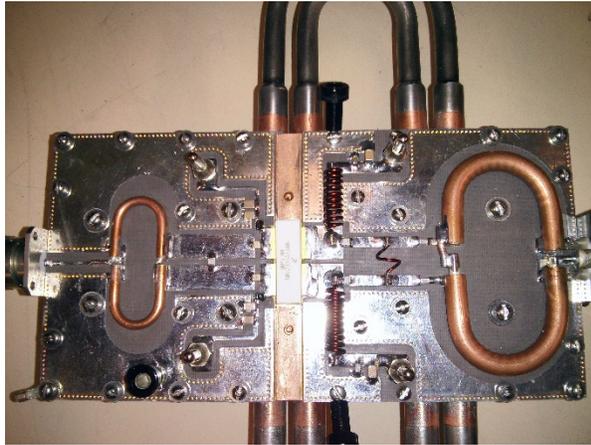


Fig. 15. The first 352-MHz/2kW prototype amplifier after electrical assembly.

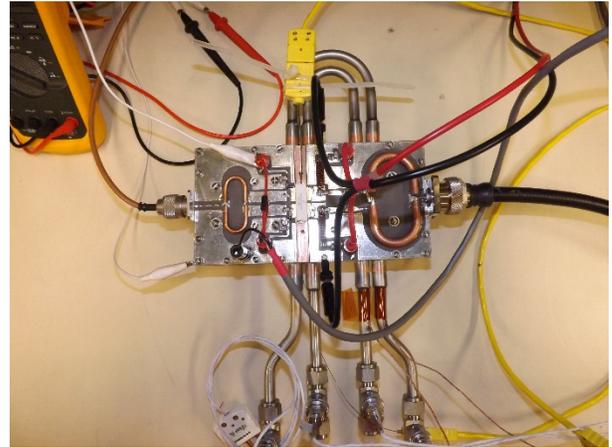


Fig. 16. Prototype 352-MHz/2kW amplifier undergoing dc-only tests to measure thermal performance of the carrier/cold-plate assembly.

A nano-bonding technique is being explored as an alternative to soldering for establishing an adequate electrical and thermal bond between the transistor flange and carrier, and between the circuit board and the carrier. It is also being considered as an alternative to the thermal grease joint presently used between the cold-plate and carrier as a way to improve the thermal performance of the cooling system assembly. Nano-foil material has been ordered for these tests.

An alternative cooling system design, consisting of a vapor chamber cooled by a thermally-bonded water jacket is also being explored as alternative method for cooling solid state amplifiers. A pictorial view of this approach is shown in Fig. 17. Work is underway to further refine this proposed design in order to estimate the cost.

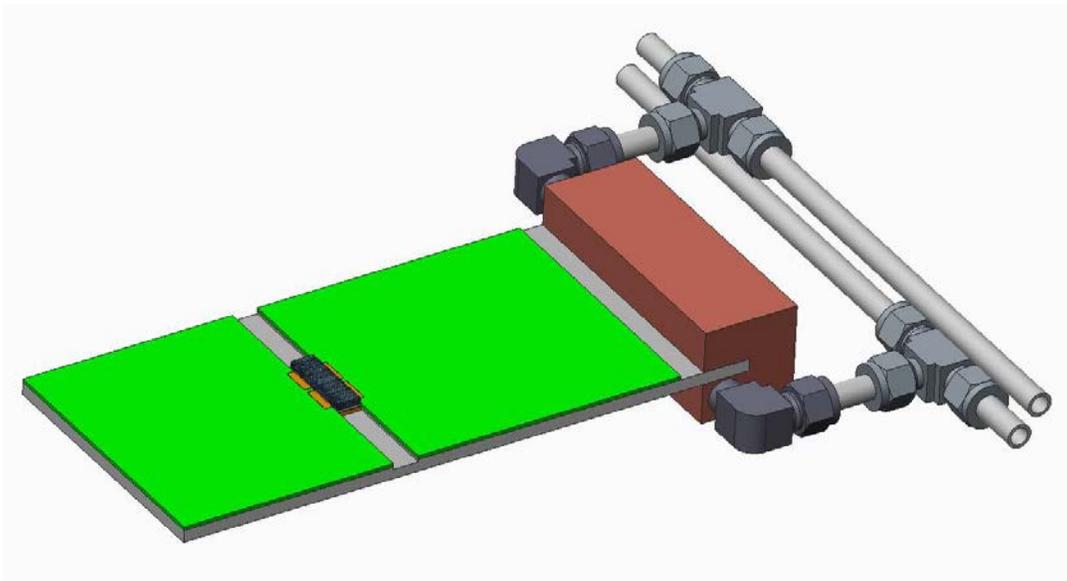


Fig. 17. Vapor-chamber/water jacket cooling concept for solid state rf amplifiers.

Additional progress has been made to develop an in-house design for a new 9.77 MHz driver amplifier that will replace the existing obsolete amplifiers presently in use in the Fundamental PAR rf systems. Further testing of prototype amplifier #2, utilizing the Freescale MRFE6VP61K25HSR5 LDMOS transistor, has demonstrated that the amplifier can operate at a continuous output power of 408 W cw utilizing an air-cooled heatsink (see Fig. 18). The efficiency exceeded 82% when operating with the harmonic filter in place between the amplifier output and the test load, and the amplifier required only 0.626 W of rf drive to achieve over 400 W of output power. Thermal imaging of the amplifier after sustained cw operation at 422 watts output (see Fig. 19) indicated that supplemental cooling of the output transformer may be necessary to maintain ferrite core temperatures below 50°C under sustained cw operating conditions. An additional fan installed for this purpose is seen in Fig. 20.

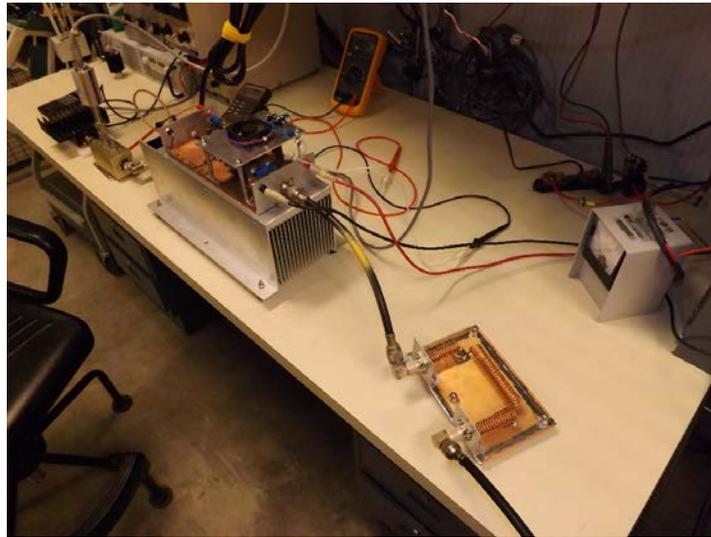


Fig. 18. 9.77 MHz prototype amplifier #2 undergoing rf testing with harmonic filter in output line.

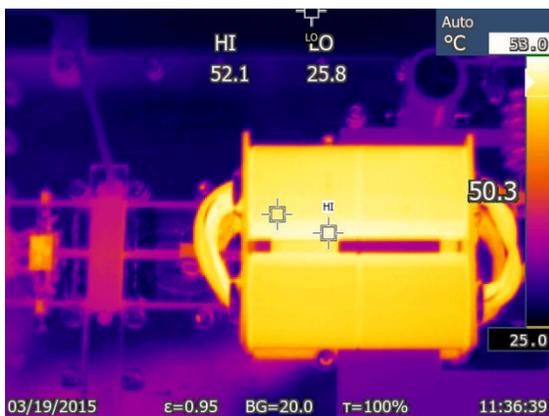


Fig. 19. Thermal image of output transformer after sustained cw operation.

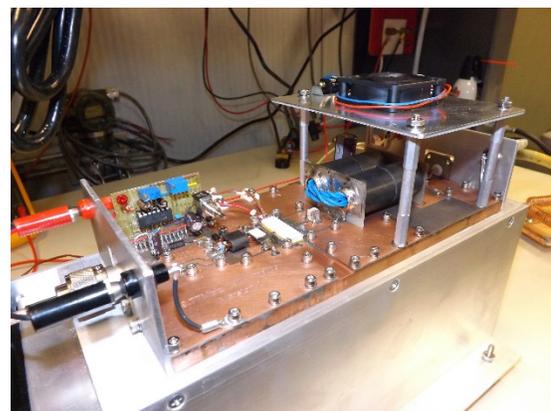


Fig. 20. Amplifier fitted with output transformer cooling fan.

Testing of this prototype amplifier in the PAR rf system under beam conditions has been planned. If these tests are successful, four production versions of this amplifier will be built in-house to replace the existing obsolete driver amplifiers in the PAR rf systems.

Several developments related to a group activity in the APS-U project took place. 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 has been dismantled and relocated from its original location in Building 400A-3 to 400A-2, where it is being re-assembled for initial L-band testing (see Fig. 21).



Fig. 21. MPA system relocated to Building 400A-2.

A portable ac power distribution system for the MPA was constructed (see Fig. 22). This system was designed to provide single-point LOTO for the MPA system when it is used as an rf power source for a test stand. During the re-assembly process in 400A-2, a threaded rod failed on the MPA high-voltage tank (see Fig. 23), and the remaining three rods were bent. All four rods were successfully replaced, and the high-voltage tank was re-assembled without problems.



Fig. 22. MPA portable ac power distribution panel.



Fig. 23. Threaded rod replacement on MPA high voltage tank.

WR-650 waveguide components necessary for initial tests of the MPA with the L-band IOT were borrowed from Fermilab (see Fig. 24). Assembly of the test setup waveguide system will begin as soon as flange gaskets arrive from the vendor.

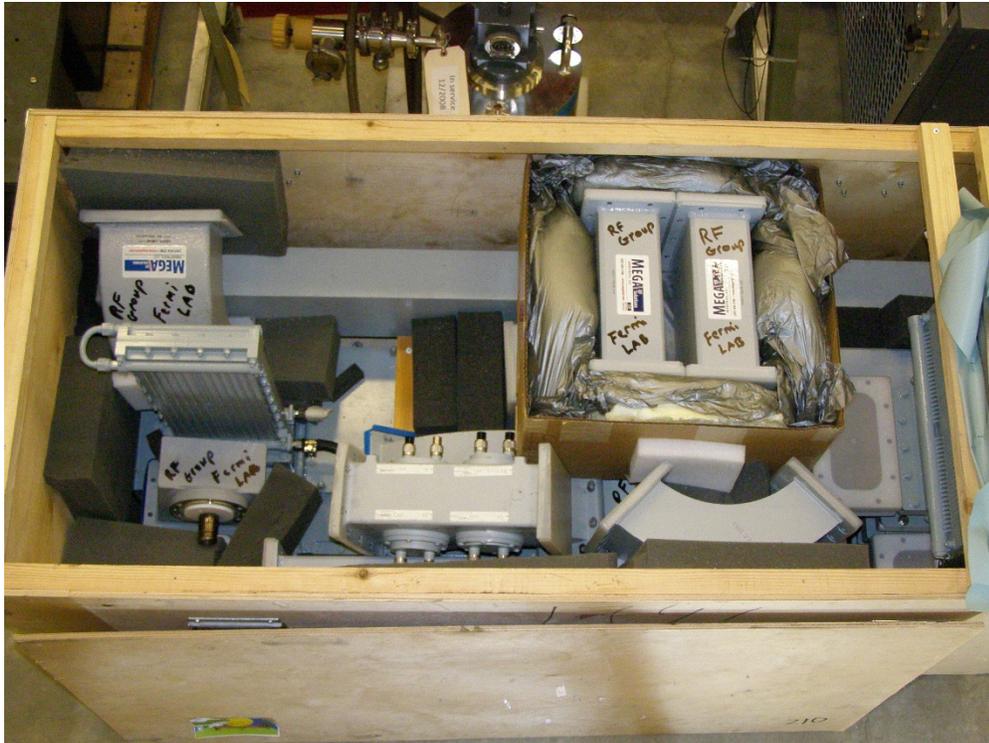


Fig. 24. WR-650 waveguide components necessary to build L-band test system for the MPA.

Steady progress has been made in LDRD work on deposition of thin film MgB_2 on large (2") copper discs using HPCVD (Hybrid Physical Chemical Vapor Deposition) process. A major challenge to deposit MgB_2 on large samples has been the uniformity of MgB_2 on the entire copper surface. Although successful deposition were done of good quality films on small copper and large sapphire samples with acceptable surface resistivity at 10 – 20 degree K and a reasonably high Q, reproducing the same results on 2" copper samples was not successful. However, production of better quality thin film samples (see Fig. 25) became possible after recent hardware modifications to the thin film deposition setup and modification to the deposition recipe.

These new samples are planned to be tested at both JLab and SLAC using two different cryostats to measure surface resistivity, quality factor, and surface fields of the MgB_2 as a function of sample temperature.

An ongoing parallel effort at Argonne is focused on using Plasma-Assisted Atomic Layer Deposition (PA-ALD). PA-ALD makes it possible to produce conformal deposition of MgB_2 on large copper samples. Upon successful demonstration of thin-film MgB_2 on large copper samples, we plan to do deposition of MgB_2 on elliptical sing-cell niobium and copper cavities. This work is planned for summer 2015.

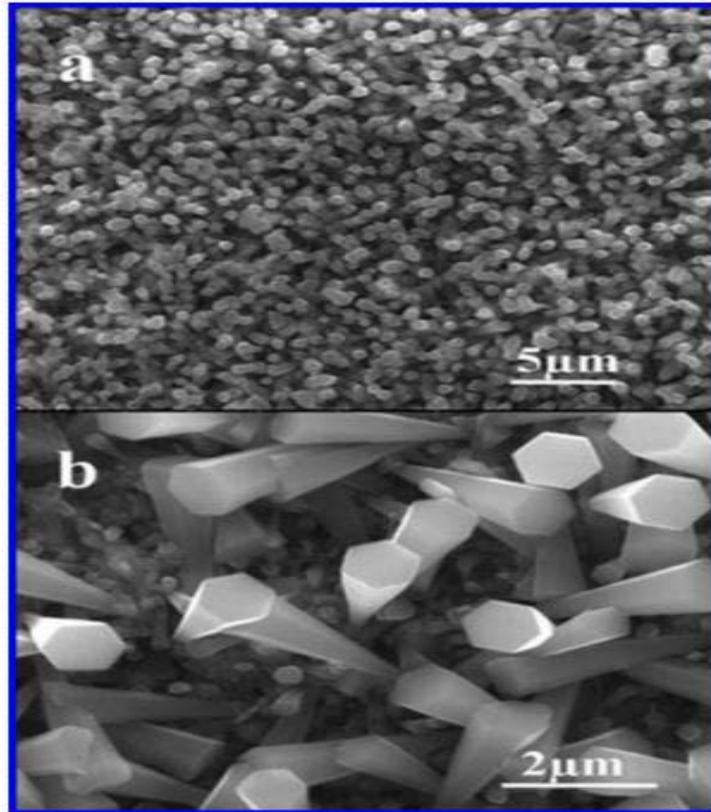


Fig. 25. (a) low- and (b) high magnification SEM images of the MgB_2 whiskers grown on a 2-inch copper substrate.