Accelerator Systems Division provided excellent support for APS operation and finished Run 2016-3 with 110 hours of the Mean Time Between Faults (MTBF) and 98.6% of the Machine Availability. Achieving this result was more difficult than usual in this run. Specific difficulties are discussed in the reports of the AOP and the RF groups. Several other developments and events took place in the fourth quarter of 2016 and are also highlighted here.

The Accelerator and Operations Group

The AOP group spent significant time in the past run trying to preserve user operation while facing several nonstandard issues with the electron beam.

First, on October 25 the injection efficiency suddenly dropped from 80% to 40%. User operations were not affected at that moment due to the availability of the high charge from the injectors. It was explained later that during subsequent machine studies a 0.8-mm-high aperture limitation was found in the 5-mm gap ID-4 vacuum chamber. It was impossible to accumulate 16 mA single-bunch current in the hybrid bunch mode of operation with this aperture limit and only 12 mA was delivered. However, the aperture limitation disappeared (mostly) a week later without any external action and the injection efficiency returned to a normal as well as the ability to accumulate 16 mA in the single bunch.

Second, the beam lifetime in 324 bunches fill pattern dropped to approximately one third of a nominal lifetime for this operational mode. Extensive studies showed presence of ions that points to a vacuum degradation, but no vacuum gauges showed sufficiently high pressure that would explain a drop in the lifetime. This prompted beam delivery with 6-hour injection intervals instead of 12-hour intervals. Even with shorter intervals, the beam current decay was still too large for some users, and, thus, the top-up was used in the second part of the 324 bunches operational mode. Further investigations pointed to a high pressure in the neighborhood of S36 cavity and a vacuum leak was found in the nearby abort kicker later. However, this pressure bump was relatively minor and only affect the 324 bunches operation. The lifetime in operation with 24 bunches was only modestly affected.

Group members continued working on the lattice design for the APS Upgrade. Beam loss simulations were performed for the latest 41-pm lattice and new ID configuration. Tracking studies for ID effects using kick maps were started. Ion trapping and related instability for the 41-pm lattice using realistic pressure profile were simulated and showed vertical instability for 324 bunch mode with round beams. The instability can be suppressed using fill patterns with short gaps. The commissioning simulation using more realistic approach based on tracking was performed. It helped to find the correlation between the quality of the lattice correction and the beam lifetime and the limitation of the accuracy of the lattice correction. The group members participated in the mini-Machine Advisory Committee in December.

Among other things, APS linac interleaving operation design review was held in November and the mini-review of the LEA experimental chamber was also conducted around the same time. Booster BPM related software was updated to work with new BPM hardware.

The Magnetic Devices Group

SCU Status

Both 18-mm period superconducting undulators SCU18-2 in Sector 6 and SCU18-1 in Sector 1 are in continuous user operation. During SCU18-2 first operating cycle, twelve different user groups have benefited from the flux increases of a factor of four over that of the APS undulator A.

The final 1.2-m long helical superconducting undulator (HSCU) core fabrication and sector 7 preparations for the HSCU installation are in progress. All HSCU major procurements are on schedule. The magnetic model for a new undulator SCAPE capable to a variable polarization has been built. The conceptual design of the SCAPE magnet is in progress.

APS-U

The magnetic field measurements were performed to determine mutual influences of the A001 quadrupole and neighboring sextupole and the A004 quadrupole and the neighboring sextupole and showed negligible couplings. DC magnetic measurement on the 8-pole corrector have been completed and agreed well with the model. The corrector magnet fabrication has been completed. Testing of the DMM and magnetic analysis of the Q2 through Q8 and M1 through M4 are in progress. New ID vacuum chamber design have been developed.

LCLS xLEAP wiggler

The magnet and pole keeper and all the other mechanical components and assembly tools have been fabricated. The device assembly has been completed. The control system has been verified. Final mechanical and magnetic tuning has been completed and processed. The device is ready for shipment.

The Power Systems Group

Operations

In the last run, there were six power supply related beam losses for a total downtime of 4 hours. The PS statistics for the run is 284 hours of MTBF and 99.74% availability. Among six power supply failures, five were due to glitches in S40B:V4 power supply and one from S19B:Q3 power supply. It was later found that S19B:Q3 power supply failed due to a workmanship issue. The input bus of the power supply was not properly tightened resulting an overheating condition and eventually an open circuit. It’s worth noting that there were no other quadrupole converter failures which is a good sign that the recently completed upgrade of all quadrupole converters is paying back. The next focus is on the sextupole and corrector magnet power converters, i.e., on identifying aging capacitors and power components and replacing the old components with the new ones. In the injector area, the focus is on satisfying the demand from the PC gun R&D and renewed LEA R&D activities.

APS Upgrade

Several important activities were carried out for the APS Upgrade. The power supplies and the power supply controllers developed and installed in sectors 27 and 28 for the Beam Stability R&D have performed well. The stability studies have achieved good results. Updated the power supply schedule to follow the Upgrade funding profile and the long term schedule. Work continued on the R&D for the precision current measurement and calibration system. The preliminary designs of the unipolar power supplies and the fast corrector power supplies have begun.

The RF Group

General RF System Operation

The rf systems experienced five faults that triggered storage ring beam loss events and three injection-related trips in the past run. Causes for the rf system faults include the failure of one klystron, RF1 and RF2 crowbar events, interlock trips caused by a defective PLC analog input module in the Sector 36 interlock system, RF2 trip on T-R Set over-temperature caused by a defective temperature sensor, and one Sector 40 rf cavity vacuum trip. The run was completed with 0.94% downtime and 254.2 hours mean-time-to-fault.

Linac-PAR

Performance of accelerating structure L2:AS2 was monitored over the run. RF input power was reduced from 80MW to 66MW to reduce reflected power trips. Subsequent supplemental grounding of the VSWR chassis at L2 eliminated nuisance trips suspected to be caused by noise. No L2 VSWR trips have been noted since the grounds were installed with L2:AS2 input power running at 66MW. L2:AS2 conditioning was conducted during the first two days of the maintenance shutdown in order to further evaluate the structure condition. As the result the RF power level was increased to 75 MW for the operation in the next run period.

Abnormal spiking and repetitive vacuum activity was detected in the L5 klystron output waveguide. The behavior of the pressure increases suggested the possibility of a water leak into the waveguide from either a waveguide window or the klystron output window. Subsequent off-line tests on other waveguide windows of identical design indicated the same vacuum pressure pattern at identical power levels of 17-18 MW.

Linac accelerating structure IHEP-01 was mounted on a strongback with new supports. RF measurements were mace on the structure, and it was vacuum leak-checked.

The fabrication of Linac waveguide pieces for general spares was completed, but two directional coupler included in the production run failed leak tests. Repairs are underway to remove leaking ceramics and re-braze the pieces.

Construction of the first new low-level rf power supply chassis prototype was completed, and the unit was tested in service at L3 and L6. A 3-4dB reduction in 60Hz-related noise on rf signals was noted during the tests.

Progress was made on construction of spare Linac LLRF modules and chassis, including one new Vector Detector Module and a Driver Amplifier Interface Chassis to be installed in L1 over the upcoming shutdown.

Production of five new rf driver amplifiers for the Fundamental PAR rf systems was completed. All five amplifiers were bench-tested at full output power into a load with no problems noted. Installation of one new driver is planned for this coming shutdown.

Booster-Storage Ring

A problem with elevated vacuum pressure developed in Sector 36 rf cavities #3 and #4, making it necessary to increase the cavity vacuum interlock trip point in order to maintain rf system operation. Subsequent vacuum system troubleshooting indicated that the abnormally high pressures are being caused by a leak in the abort kicker structure (see above in AOP report), which is located just downstream of Sector 36/Cavity #4.

Bead-pull tests were conducted on a spare storage ring rf cavity to characterize the fundamental and next three longitudinal higher-order modes.

The first production version of the storage ring tuner motor drive electronics was assembled. It is presently being installed in the RF Test Stand for final testing.

Thales klystron s/n 089024 failed in service at RF1 at approximately 1,200 hours of operation due to the sudden onset of very high dc leakage in the gun, unstable rf power output, very low gain, and very poor efficiency. High-voltage conditioning of the gun was attempted, but no significant improvement was noted. The klystron was removed from RF1 and replaced with a spare. It will be installed in the RF Test Stand klystron garage for further evaluation.

One of the two 352-MHz Los Alamos E2V klystrons that were re-tuned in 2011, s/n 005, was successfully installed in RF1. Start-up of the klystron was very smooth and uneventful, and it was successfully operated both into the rf test load at 850kW and supporting storage ring beam. Several unexplained crowbar events at RF1 that occurred after the klystron was installed were determined to be caused by poor contact in one of the klystron high-voltage connectors, and two defective high-voltage cables that connect the klystron to the power supply. All three high-voltage connectors on the klystron were cleaned and rebuilt, and the two defective cables were replaced. RF1 system operation returned to normal.

A new spare rf system Matching Transformer was received.

350-MHz RF Test Stand
RF sweep measurements were performed on the first of three EEV klystrons received from Los Alamos, s/n 02, in order to measure the resonant frequency of cavities 1, 2, 4, and 5 prior to re-tuning to the APS operating frequency. Initial cavity tuning will be performed over the shutdown, with power testing to resume sometime in late January.

New storage ring tuner ANL-27 developed very high localized rf finger temperatures while being conditioned. The tuner was removed from the test stand cavity and analyzed. It was determined that the local heating was caused by multiple broken fingerstock contacts on the piston. The tuner is presently being repaired for a second attempt at conditioning.

Solid State RF Development
With the exception of the rf contact springs, all hardware pieces necessary to build the 12kW cavity combiner have been received. Assembly of the output waveguide and coupling jack has started. Procurement of a 70V/650A dc power supply needed for the 12kW test is underway. Construction of the remaining four 2kW amplifiers needed for the 12kW test is approximately 25% complete. An assembly/test area for the 12kW system is being prepared in Building 400A on the mezzanine over the Solid State Lab.

The Diagnostic Group

Diagnostic group successfully completed a so-called 4x4 test in the second quarter. In this test, DIAG group verified basic functionality of the feedback controller hardware based on DSPs and FPGAs capable of receiving turn-by-turn data from the Libera Brilliance+ bpm electronics and updating corrector setpoints at 22.6 kHz. The 4x4 test demonstrated a closed loop bandwidth of 450 Hz which is approximately 4.5 times broader than that achieved with the operations RTFB system running at 1.5 kHz update rate. Another important measurement made during the 4x4 test was the relatively large latency through the system (~250 ms) due mostly to the existing fast corrector power supplies.

With successful completion of the 4x4 test in the second quarter, the diagnostics and controls groups installed most of the hardware required for the next phase of orbit feedback system testing called the “Integrated Beam Stability” (IBS) test. The main goal of the IBS test will be to test a full functional unit of the APS-U orbit feedback system. Installation of the additional hardware was completed during the September 2016 shutdown. The new hardware includes: new prototype fast corrector power supplies and interfaces to four fast correctors in sectors 27 and 28; slow corrector power supplies with a modified interface to the feedback controller; a nearly full double-sector complement of sixteen rf bpms; hydrostatic and capacitive mechanical motion sensors; GRID Xray bpms and user beamline position-sensitive diagnostics. Main goals of the IBS R&D are to integrate the orbit feedback system hardware with the existing EPICS based machine control system, demonstrate a unified orbit feedback algorithm that incorporates both fast and slow correctors and three tiers of beam position sensor bandwidths (rf, Xray, mechanical motion) and integrate the fast DAQ with the feedback controller for collection and analysis of turn-by-turn bpm data and synchronous 22.6 kHz orbit-feedback data. Results of IBS R&D will inform the final design of the orbit feedback system to be able to achieve challenging stability requirements of the

APS Upgrade (AC bandwidth from 0.01 to 1000 Hz with only 400 nm rms beam motion in the vertical plane and 1 mm rms long term drift for timescales > 100 seconds).