

UPDATE ON APS ACCELERATOR SYSTEMS



JOHN BYRD
ASD
Photon Sciences Directorate

PSC All Hands Meeting, 28 July 2021

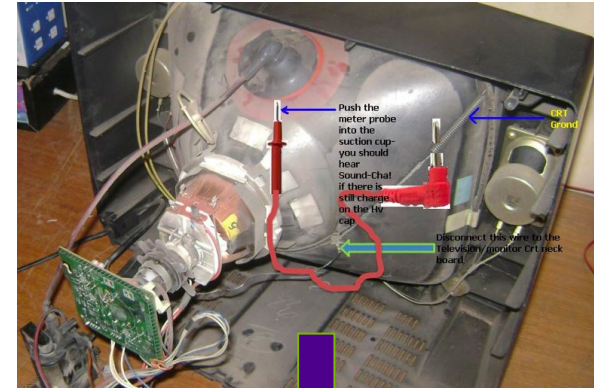
OVERVIEW

- APS Accelerator Infrastructure Initiatives
 - Storage Ring Solid-state RF upgrade
 - APS Linac Refurbishment
- Using the APS as a testbed for APS Upgrade
- Accelerator R&D Initiatives

FROM TUBES TO TRANSISTORS: UPGRADING THE STORAGE RING RF SYSTEM TO SOLID-STATE

A critical need to maintain operation beyond the APS Upgrade

- The original APS RF system is based of MW-class klystrons that no longer are being produced. All modern telecom systems are based on solid-state amplifiers.
- The APS High Voltage systems are also approaching end-of-life and will need replacement if we stay with klystrons.
- We are embarking on a plan to convert the APS storage ring RF system to solid-state amplifiers with goal of replacing the existing system before the last klystron fails!
- We have ordered the first 200 kW SSPA with delivery expected in April 2022.



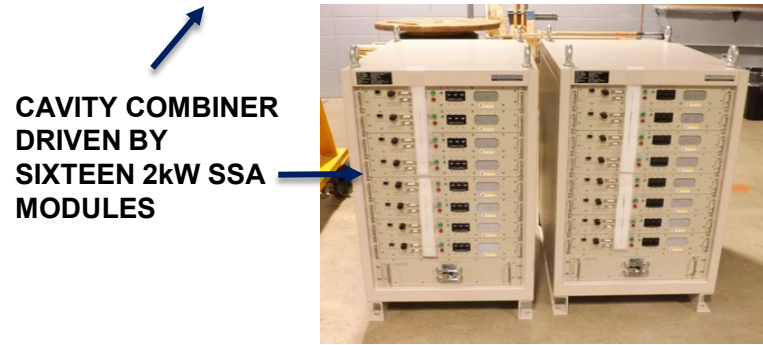
THE SOLID-STATE RF PLAN IS BASED ON SEVERAL YEARS OF ENGINEERING R&D

We have settled an array of 2 kW amplifiers combined using a “barrel” cavity.

- A long campaign has validated the overall RF system concept
 - Procurement of a commercial 32 kW unit of 16-2 kW amplifiers that has been exhaustively tested.
 - Validation of the “combiner” cavity concept with measured power levels and losses agreeing well with predictions. Included a “backfeed” test using 200 kW from a klystron to test at high power.
 - Overall system layout concept consistent with APS space and infrastructure (i.e. power and water)



CAVITY COMBINER

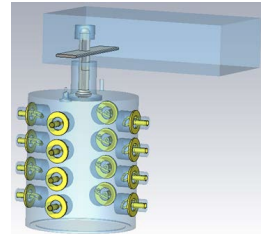
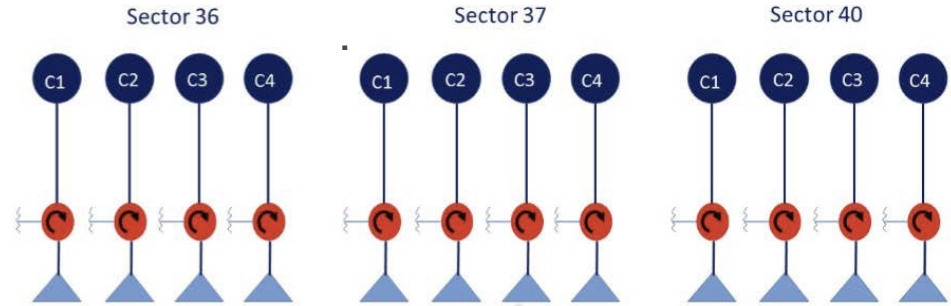


CAVITY COMBINER
DRIVEN BY
SIXTEEN 2kW SSA
MODULES

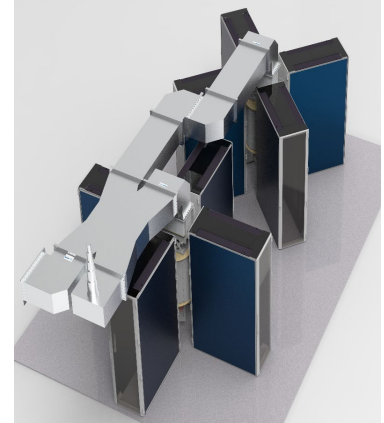
THE NEW RF SYSTEM IS DESIGNED TO HAVE MULTIPLE REDUNDANCIES

Fewer single points of failure will give higher reliability

- Each cavity requires one solid state power amplifiers (SSPA) system
- SR will need 3 sets of 4 cavities each at S36, S37 and S40
- Each of the 12 cavities will require 160kW* of RF power
- 4 SSPA systems are needed to replace 1 klystron amplifier
- Total of ~2 MW power needed.



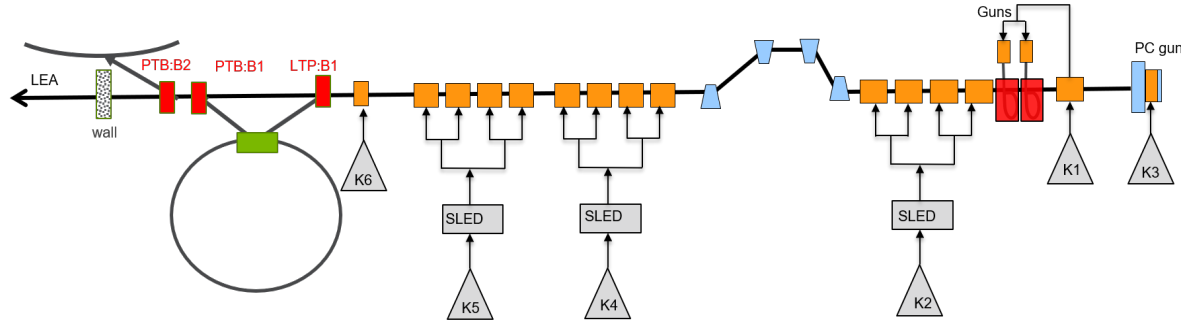
Modular concept of each RF station



Cost of solid-state amplifiers is \$10/W. Total cost of system expected to be \$25-30M.

REFURBISHING THE APS LINAC FOR THE NEXT 30 YEARS OF APS OPERATIONS

The aging APS linac needs refurbishing to meet operations needs.



- APS-U will have frequent swapout injections of **whole** bunches requiring increased performance and reliability of injector system, including the linac.
- The linac cannot provide the anticipated beam energy needed for APS-U 48-bunch operation (475 MeV). Needs an updated RF system.
- Many other antiquated subsystems that are at end-of-life.
- A full plan to upgrade and update obsolescent subsystems has been put together by Yine Sun.

FIRST PHASE OF REFURB IS IN PROGRESS

First new HV Modulator, klystron, and digital RF controller received.
Second system expected later in 2021.

- Testing of first received system underway in new Utility Shed constructed in APS infield.
- Installation in APS linac expected later in 2021. If successful we will move forward with more installations and procurements.
- Designs and specs for new RF guns, power supplies, timing system, diagnostics, etc. are complete and awaiting funding.



DETAILS OF THE LINAC REFURB PLAN

All projects have been initiated under guidance of the APS PMO

1st 50MW RF
klystron/modulator

Digital LLRF
System

Bldg 413 LINAC
High Power RF Test
Stand

More 50MW
RF Stations

Thermionic RF
Guns

Replace Linac
Water Skids

Fast Interleaving
Alpha magnet

Injector Network
Upgrade

Linac Corrector
Power Supplies

LINAC Timing
System

Linac RF Windows,
Switches, SLED &
Accelerating
Structures

Linac BPM
Electronics
Replacement

Linac Current
Monitors and
Electronics
Upgrade

Digital Cameras for
Linac Flaps

Total cost of \$8-10M. Initial steps funded by APS Ops.

Funded Project

Partially approved project

demands

PREPARING FOR APS-U USING THE APS

Address potential challenges with tests in the APS simulating APS-U

- Automated commissioning
 - Develop and test APS-U automated commissioning algorithms using a “scrambled” APS. Critical for short APS-U commissioning schedule.
- BPM Development
 - Test the APS-U Beam Position Monitor at high beam current and the long-term stability of the Signal Processing Electronics
- Next-generation Fast Orbit Feedback (FOFB) development and testing
 - Testing a prototype of the kHz bandwidth FOFB on the APS.
- Understand ion trapping effects and validate APS-U ion modeling
 - Conduct a comprehensive experimental study to compare ion trapping effects with computer modeling and test ion trapping mitigation schemes
- Characterize the RF cavity higher-order modes for proper tuning in APS-U
 - We have developed a state-of-the-art technique using the new digital multibunch FB systems purchased for use in the APS-U.
- Understand the effect of the high energy density APS-U beams impacting vacuum chamber components
 - There is concern for the durability of the APS-U collimators when hit by the very bright APS-U e-beam. A modeling and experimental is underway to understand these effects.

DOE-SUPPORTED ACCELERATOR R&D IS FLOURISHING

Argonne accelerator capabilities are attracting funding.

- Superconducting Undulator Development
 - Goal of 20-30% field increase using Nb₃Sn wire. Early prototypes have performed extremely well. Awaiting full length cores for last push and APS test.
 - Demonstration of SCUs in an FEL. Received recent news that joint proposal with SLAC will be funded at ~\$5M.
- Cavity-based XFEL
 - Joint **What is the next light source for Argonne?** ing at potential for brightness increase in FELs in Argonne responsible for optical resonator.
- Superconducting RF Gun
 - Completed testing of WIFEL SRF gun. Potential application as UED/UEM source. This has already led to funding of a joint MSU/HZD/Argonne proposal to build the LCLS-II/HE SRF gun. Funded at ~\$7M.
- Significant progress on LDRD-funded advanced concept on compact linear accelerator.
- AI/ML for Accelerators-Funded proposal for machine learning applications for accelerator operations. Funded at \$300k/yr for 3 years.

SUMMARY

- We have defined plans for replacement of storage ring klystron-based system with solid-state amplifiers. The first unit has been ordered and arrives in 2022 for testing
- We have a plan for refurbishing the APS linac in preparation for the next 30 years of APS operations. First two RF stations are ordered with first installation expected later in 2021.
- Both of these initiatives could total \$40-50M in resources. We are working with BES to identify a way to move forward.
- We are using the APS whenever possible to test subsystems and concepts for APS Upgrade.
- We have a healthy portfolio of accelerator R&D projects.
- **Develop a strategy for the next accelerator facility Beyond APS-U.**