ACCELERATOR SYSTEMS DIVISON (ASD)

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PSC All-Hands and Priority Meeting
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ACCELERATOR SYSTEMS DIVISION: 20/20 VISION

Modernizing the APS Accelerator Complex for a new brightness era

- In 2020, APS will reach 25 years of user operation as the "crown jewel" among DOE light sources due to highly skilled and dedicated staff.
- By 2025, we will be operating a new ring that will lead the world in hard x-ray sources.
- **ASD will be preparing for this over the next three years!**
  - Revamping of injector systems to provide 20 nC/pulse
  - Modernization of Main Control Room instrumentation and diagnostics.
  - Development of efficient and high reliability RF sources beyond klystrons
  - Design and production of new generation of IDs
  - Develop and build 2284 new PS
  - Succession planning to maintain highly skilled staff
  - Accelerator R&D that looks beyond APS Upgrade

MODERNIZATION OF APS ACCELERATOR COMPLEX

Many of the APS subsystems use analog systems designed in the early 1990s

- Much of the APS accelerator systems, especially the injector, still use the analog control electronics developed for commissioning in the 1990s.
- New demands for APS upgrade require the injectors to perform 10 times better than at present.
- Many of the diagnostics around the complex and MCR are also 25 years old.
- **Time for renovation!**

State of the art cell phones in 1990

ASD HAS A COMPLETE WORLD-CLASS ACCELERATOR DESIGN TEAM FOR NEXT GENERATION RINGS

APS Develops, Distributes, and Maintains ELEGANT: One of the Primary Tools For Accelerator Design and Development.

- Next generation light storage ring light sources push the beam emittance so low that all known beam physics must be considered to reach the performance:
  - Nonlinear dynamics from strong sextupole fields
  - Intrabeam scattering from the high electron bunch density
  - Bunch lengthening using harmonic cavities
  - On-axis swap-out injection requiring 20 nC/pulse from our injectors.
  - ……..
- ASD is the world leader in developing tools to understand the interaction and optimization of all of these effects **BEFORE** we build the accelerator.
- APS has a magnetic design and engineering team that can create real magnets, girders, vacuum chambers, and power supplies that meet the extreme demands of the accelerator design.

ASD HAS WORLD-CLASS ACCELERATOR PHYSICS TEAM

- **Supports highly reliable APS operation**
  - Develops and maintains software for accelerator control automation, accelerator data collection and analysis
  - Analyzes reasons for beam losses
  - Evaluates effects of new installations
- **Leads APS-U accelerator design effort**
  - Development and optimization of the extremely low-emittance lattice
  - Injector development and modification to achieve APS-U goal of 20 nC per pulse
  - Determining mechanical and electrical tolerances to support new design
  - Detailed beam loss simulations for shielding design
  - Ensuring the mechanical component design is compatible with high-charge high-lifetime operation
- **Develops, distributes, and maintains ELEGANT – one of the primary tools for accelerator design and development**

APS IS DEVELOPING THE NEXT GENERATION BEAM AND X-RAY STABILIZATION SYSTEM

Essential for effective use of the ultra-bright beams of APS-U

- APS-U has very challenging AC and long-term beam stability requirements for ID source points:
  - **400 nm rms position stability from 0.01 – 1000 Hz (Vertical Plane)**
  - **1 μm rms position stability over a 7 day period**
- A suite of APS-U diagnostics is tested in sectors 27 and 28 to demonstrate these requirements in the present APS storage-ring
  - **New turn-by-turn rf bpms**
  - **New Grazing Incidence Insertion Device X-ray BPMs**
  - **New orbit feedback system with update rate of 22.6 kHz (present system - 1.5 kHz)**
  - **Mechanical positon measurement systems to correct for mechanical motion of the ID rf and X-ray bpms**
- Demonstrated 400 nm rms AC stability in experiments in April 2017[1]
- Demonstrated correction of long-term bpm position using mechanical measurement system[2]

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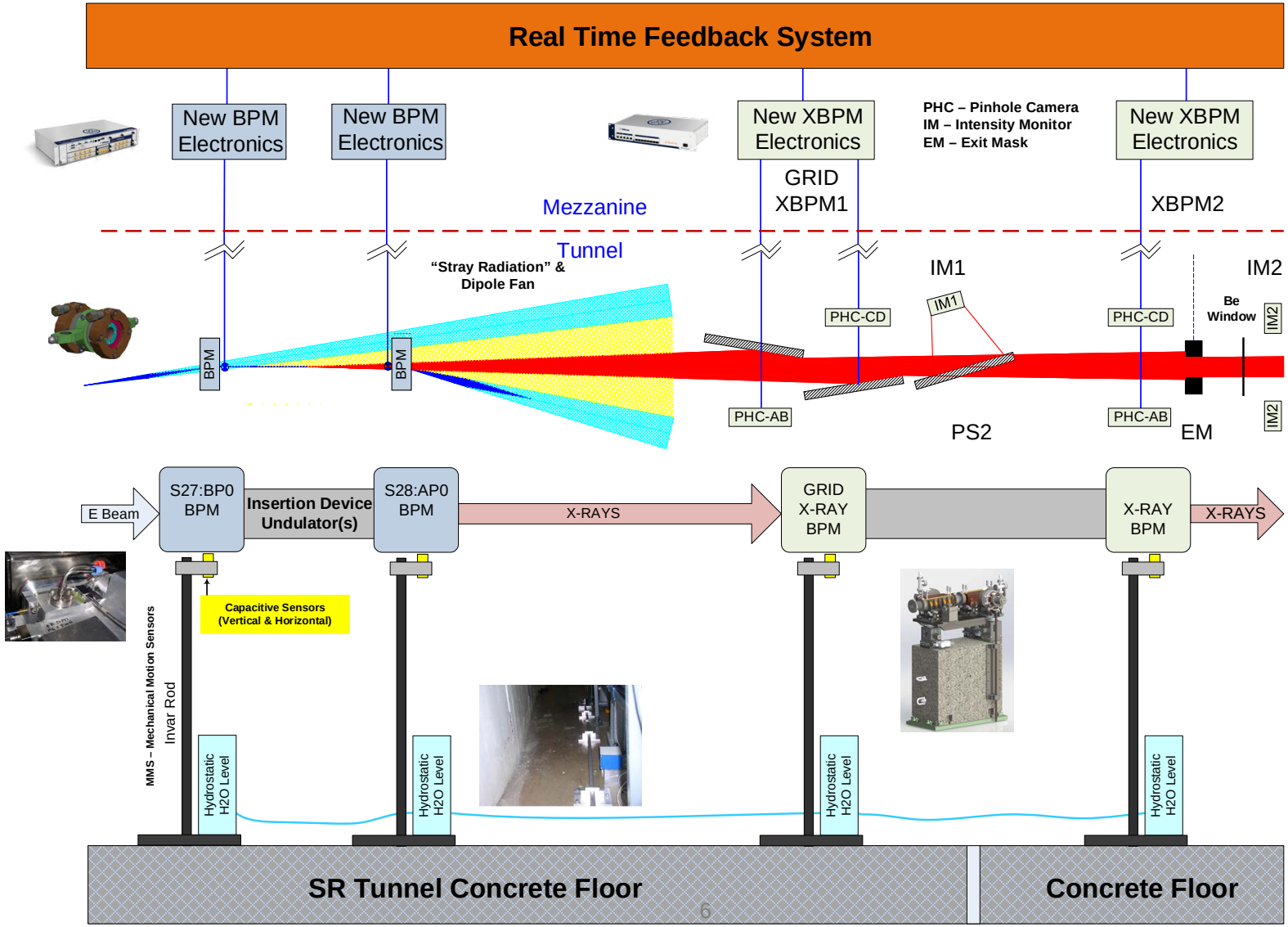
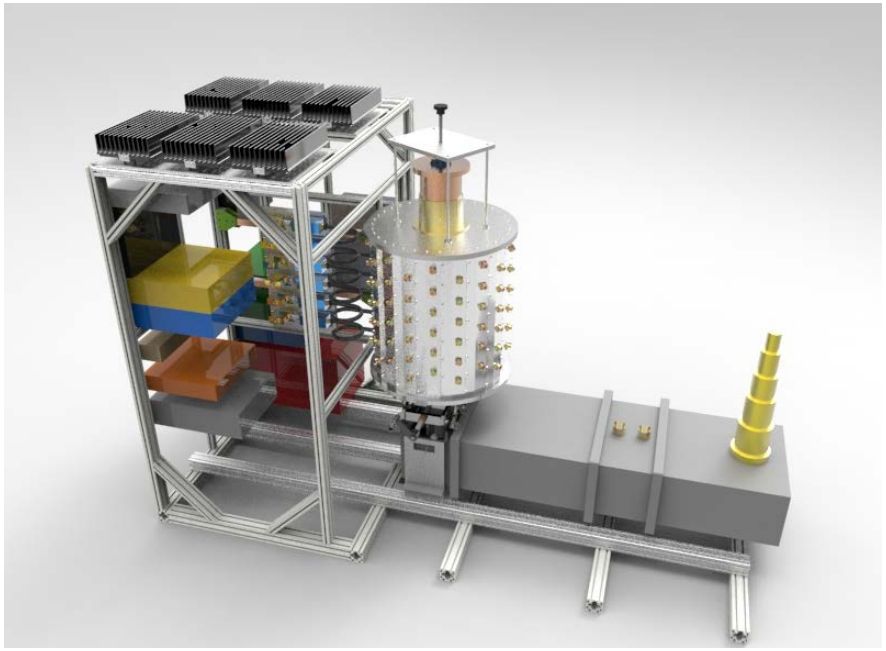
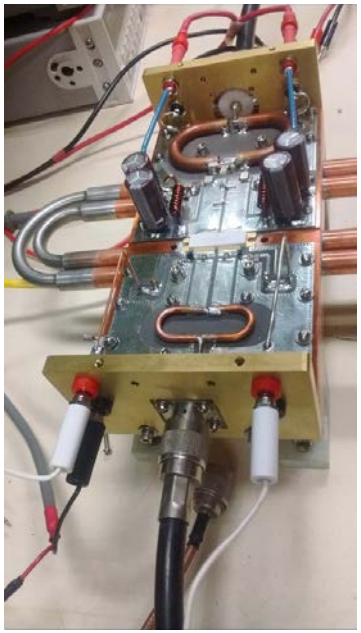


ENSURING RF SYSTEM PERFORMANCE FOR THE APS FUTURE WITH A PLAN B

- With the decreasing number of vendors and rising costs of tube-based rf sources, we are pursuing R&D towards alternate rf sources. The main candidates are modular solid-state rf sources.
- LDRD support has led to a possible design that has 100-2 kW SSAs combined to give a single 200 kW amplifier driving a single cavity.

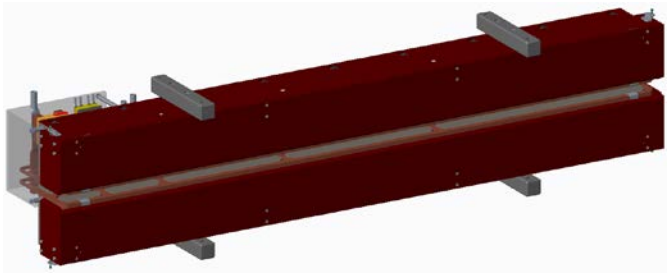


ASD RF Group SSPA concept

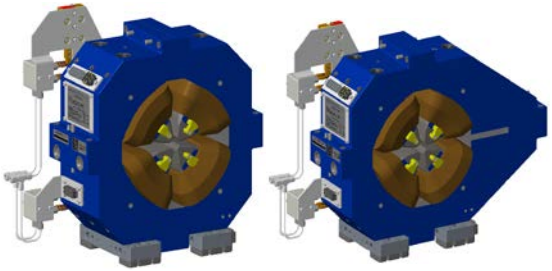


Single 2-kW module

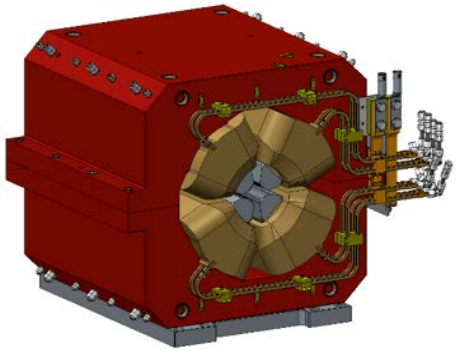
APS-U STORAGE RING MAGNETS



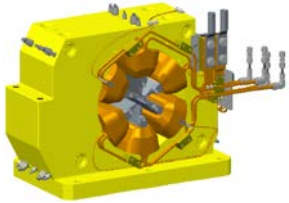
L-Bend Magnets (M1, M2)



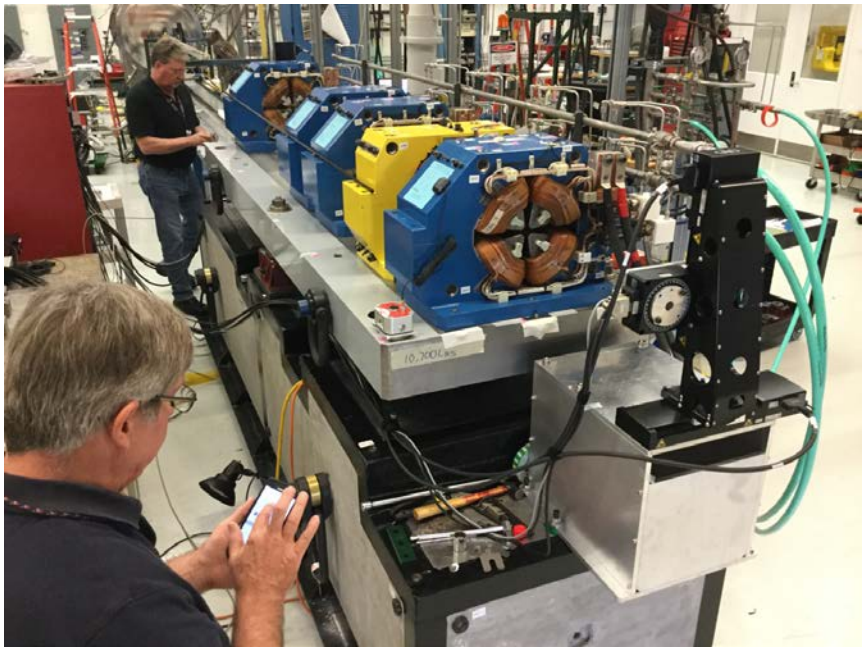
Q1, Q2, Q3, Q6 and Q7
Quadrupole Magnets



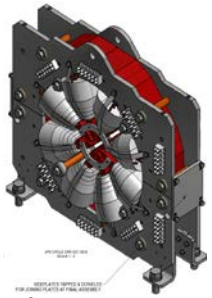
Q-Bend Magnets
M3,M4



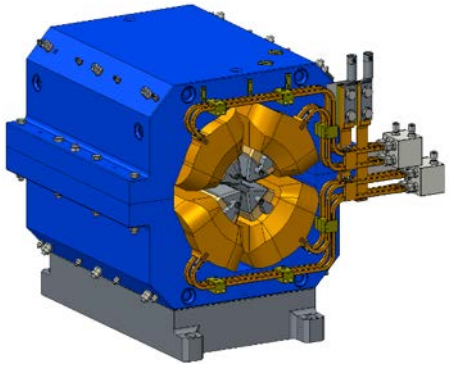
Sextupole Magnets
S1- S3



APS-U DMM magnets on the magnet measurement test stand



8-Pole Corrector
(FC1 and FC2)



Reverse bend Quadrupole
Magnets
Q4, Q5, and Q8

MAINTAIN HIGH RELIABILITY POWER SUPPLIES FOR APS OPERATION, DEVELOP NEW SYSTEMS FOR APS-U

- Maintain existing power supply systems in both storage ring and injectors to keep excellent availability, greater than 99.5% on average, for APS operations.
- Identify and upgrade obsolete and aging components for power supply systems that will stay beyond APS-U.
- Support accelerator R&D programs.
- More than 50% engineering resource of Power Systems Group devoted to APS-U project
  - Develop, design, and procure
    - 2284 power supplies
      - Two 500 kW rating PS for L-bend dipoles
      - 1000 unipolar power supplies with 10 ppm stability
      - 1282 bipolar power supplies for DC trims, fast correctors, and canted line magnets
    - 400 power supply controllers
  - Develop and design independent precision current measurement systems with in-situ calibration capability.
  - 100% tested before final installation.

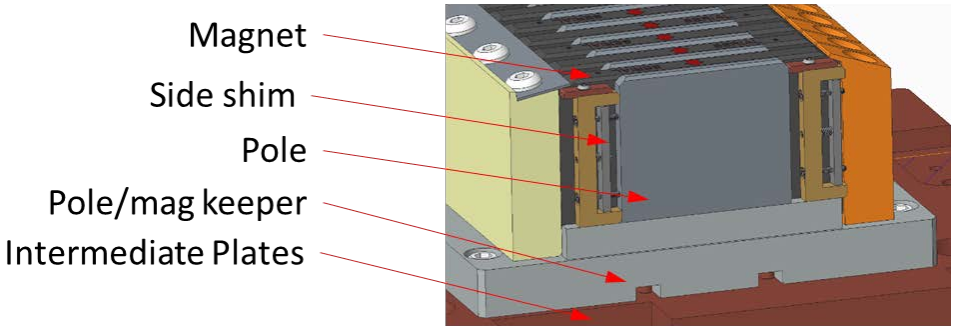
Storage Ring Power Converter

APS-U Prototype PS Controller

APS-U Prototype Bipolar Power Supply

CONSTRUCTION OF APS-U PLANAR UNDULATORS IS UNPRECEDENTED CHALLENGE

- **APS has to build, tune and install 57 planar permanent magnet undulators in the period of 12 months. None of operating facilities, such as ESRF or LCLS, are planning for such challenging replacement rate.**
- **APS ID team is developing innovative solutions for the design of undulator magnetic structures that will lead to simplified construction and tuning process.**



APS

- **R&D and prototyping of novel mechanical design, verification of the simplified shimming technique and automated tuning procedure are critical to the success of APS-U.**

APS IS THE WORLD LEADER IN SUPERCONDUCTING UNDULATORS

ASD-Magnetic Devices has an unfair competitive advantage over the entire community

- Due to early investment by the APS and leadership in superconducting undulators, we now have the skills and infrastructure to dominate this light source technology for years to come.
- SCU-18-1 and SCU-18-2 (18 mm periods) are installed and operating in the APS. Helical SCU installation on schedule for Dec 2017.
- R&D for LCLS SCU has been very successful with funding opportunities for building full-scale prototypes.
- What's next? **S**uper**C**onducting **A**rbitrary **P**olarizing **E**mitter (SCAPE). Funded by LDRD. This enables variable polarization of x-rays.