STATUS REPORT ON THE ADVANCED PHOTON SOURCE, SPRING 1990

by

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INTRODUCTION

The Advanced Photon Source (APS) at Argonne National Laboratory has been designed as a national user facility for synchrotron-radiation researchers from industry, universities, and national laboratories. In fact, the APS user community has been an important source of guidance and expertise throughout the project's planning cycle.

By providing x-ray beams more brilliant than those currently available, the APS promises to play a substantial role in any discipline where knowledge of the structure of matter is important, from basic research in materials and chemistry to condensed-matter physics, biology, and medical applications. The science now in progress at existing synchrotron-radiation facilities, and the science being proposed for the APS, underlie virtually all modern technologies.

In February of 1986, a conceptual design report (CDR) was issued detailing plans for a next-generation synchrotron-radiation machine, the 6-GeV Synchrotron X-ray Source. In April of 1987, a second CDR formalized the design of the 7-GeV Advanced Photon Source. That design has been refined and carried forward to its current level of construction readiness. On the eve of ground-breaking ceremonies, a review of APS status is appropriate.

APS FACILITY OVERVIEW

The APS facility is to be constructed in the southwest corner of the Argonne site on a 79-acre parcel of land with very good geological characteristics.

The experimental hall will be 390 meters in diameter, with the storage ring nearest the inner wall of the large hall. The linac, positron accumulator ring, and booster are to be located in the infield. Lab/office modules for users will be located around the perimeter of the ring. Staff and long-term visitors will occupy an office building situated outside the ring. The APS will provide research opportunities for several thousand scientists in total, with 300 to 400 taking data at any one time.

The 58-m-long, 60-Hz APS linac will initially accelerate electrons to 200 MeV. One-third of the way down the linac, the electrons will impact on a tungsten positron-conversion target. Positrons will be captured and accelerated to 450 MeV over the remaining two-thirds of the linac and then injected into a small accumulator ring, approximately 31 meters in circumference, where successive 450-MeV pulses from the linac will be stacked. The accumulator ring serves two functions: to damp the positron emittance, thereby making the beam more compact, and to accumulate 24 pulses from the linac while the booster is ramping-up the previous set of pulses. After injection into the 368-m-circumference booster, positrons will be ramped-up from 450 MeV to 7 GeV in one-quarter of a second. Because it cycles back down to 450 MeV in order to pick up the next pulse, the booster performs two cycles per second, making it a 2-Hz machine.

The storage ring, 1104 meters in circumference, is designed for a nominal energy of 7 GeV. All calculations of undulator spectra indicate an optimal energy range between 7 and 7.5 GeV. At higher energies, the performance of undulators in the principal x-ray range, where APS will operate, begins to deteriorate, making 8, 9, or 10 GeV problematic in terms of usefulness. Under normal operating conditions, about 30 of the 1296 available rf buckets will be filled with positron bunches, each carrying on the order of 5 milliamps. Anticipated filling time is one minute.

The APS storage ring will have 40 sectors that each include a straight section. Each sector will contain one insertion-device (ID) beamline and two bending magnets. One of the two bending magnets in each sector will be available to extract radiation; thus, a sector from the user's point of view is an insertion device and its companion bending-magnet beamline. Allowing for rf cavities and injection apparatus, there will be 34 sectors available to user groups.

APS undulators will produce x-ray beams with spectral brilliance in the range between 10^{18} and 10^{19} photons/s/0.1%BW/mrad^2/mm^2. That brilliance represents an increase of 3 or 4 orders of magnitude over what is now available from, for instance, bending magnets at the National Synchrotron Light Source. There are other devices which perform in the intermediate range, but nothing extant in the U.S., or in fact the world, is capable, certainly on a dedicated basis, of producing brilliance at the level to be achieved by the APS.

Space for users at existing synchrotron-radiation facilities has historically been in short supply. The APS design calls for one user module, containing two labs and complementary offices, for each sector of the machine, providing a significant improvement in the quality of life for the research community around the ring.

RESEARCH AND DEVELOPMENT HIGHLIGHTS

Insertion devices

A collaboration between the APS Experimental Facilities Division (EFD) and researchers at Cornell University resulted in the design of a new insertion device, the APS/CHESS undulator. APS staff then worked with Spectra Technology of Bellevue, Washington, to construct the ID, and in 1988 the prototype APS/CHESS undulator was installed at the Cornell Electron Storage Ring, where it performed extremely well.

A prototype ultraviolet undulator has now been constructed and it will soon be tested in the vacuum ultraviolet ring at Brookhaven National Laboratory. Currently under consideration is a device to produce circularly polarized radiation, an advance certain to be of interest in the atomic physics community.

Optics

The problem of thermal loading on beamline optical components is also the subject of an EFD study. When an intense x-ray beam strikes a monochromating crystal or a mirrored surface, that surface is heated, causing a distortion, or local thermal bump. These high power densities, which will occur at unprecedented levels at the APS, would be disastrous to a beam's optical quality. A multi-step procedure developed by APS staff will model the effect of localized high heat loads on optics. Using the Cornell machine and beams from the prototype APS/CHESS undulator, the results of these calculations have been intercompared with performance to determine the reliability of the finite-element-analysis approach and to optimize schemes for optics cooling adequate to the needs of APS.

While the state of the art in optics cooling has been to run water through channels close to the surface of a crystal, Argonne scientists have pioneered the use of liquid metals, particularly gallium, which is much more effective as a coolant. At the current stage of development, APS-designed optics can withstand the power densities associated with beams carrying brilliance levels in the 10^{18} range. Further optimization of that geometry will be carried out to accommodate the even greater power densities that will come with the 10^{19} brilliance level produced by the fully operational APS facility.

Accelerator physics

Anticipating the behavior of particles in a storage ring is among the most daunting of accelerator-physics issues. The APS Accelerator Systems Division (ASD) is performing a series of experiments using the Aladdin storage ring at the Synchrotron Radiation Center in Wisconsin. These experiments serve as a check on computer programs that must predict the behavior of particle dynamics in the APS storage ring, as measured in response to perturbations. Under experimental conditions, APS simulations have proven to be very accurate. The measurements also resulted in specific determinations about the operational parameters of the magnets in the Aladdin ring, conditions which were not known at that level of detail at that time, making this undertaking useful for scientists at Aladdin as well as at APS.

Vacuum chambers

There will be 240 sections of vacuum chamber, each approximately 15 feet long, in the storage ring alone. Three actual, though non-production, storage ring vacuum-chamber segments, complete with all welds, hardware, and ports, have been constructed by the Accelerator Systems Division. Fabrication of these chambers requires intricate welding to allow connection of all segments in the ring. An innovative welding technique has resulted from the R&D effort carried out with Ferranti Sciaky, Inc., of Chicago.

Configuring vacuum chambers to match ring curvature has not been a trivial matter. It was realized that if the chambers could not be bent, they would require machining, a much more expensive alternative. A method for bending the chambers, the subject of an R&D initiative begun two years ago together with Pacific Pipe of Oakland, California, has been successfully demonstrated, putting to rest a key technical and budget issue.

Magnets

As there will be a total of 1503 magnets of various types in the APS accelerator complex, R&D in this area has also been a focal point for the Accelerator Systems Division. The first of 400 APS storage-ring quadrupole (SRQ) magnets has been assembled from components fabricated to APS specifications. The SRQ, though a straightforward electromagnet, is very demanding in terms of magnetic-field quality: Storage-ring quadrupoles for the APS require field gradients accurate to 1 part in 10^4, maintainable even after disassembly and reassembly for repair. Critical parameters must also be achieved economically over the entire SRQ fabrication cycle, as they must for all APS magnets.

The prototype 0.8-m-long SRQ was transported to Fermi National Accelerator Laboratory for magnetic measurements, which proved to be within the required margin of error. Slight design modifications are now under way prior to assembly and testing of a second SRQ. In order to expedite the measurement process, an APS magnet-measurement facility is scheduled to be on line at Argonne in the summer of 1990.

FUNDING

The *7-GeV Advanced Photon Source Conceptual Design Report* proposed a construction budget of $380 million (expressed in FY1989 dollars, as are all amounts here), with $77 million of that sum for contingency and a detailed estimate totaling $303 million for technical components including the injector, the storage ring, insertion devices, and beamlines. Since then, that estimate has held up as the APS progressed from conceptual design to a completion level of 30 percent. Though costs have risen by $30 million, the contingency has dropped to $49 million as more knowledge about the design has been gained, the motivation for setting a large contingency at the outset. Escalation in the cost of conventional construction, currently estimated at $147 million versus the CDR estimate of $115 million, had been the cause of some concern. However, in the last few months, value-engineering studies have identified approximately $16 million in cost containments for conventional-facilities construction. Over all, the project cost estimate has risen by only one percent.

The schedule now on file with the Department of Energy, the Office of Management and Budget, and the Congress, calls for $40 million in FY1990 to underwrite early construction activities, as well to purchase some technical components. In FY1991, APS is scheduled to receive $75 million, with funding escalating through FY1993 and then tailing off over the next two years for a total of $456 million at completion in 1995.

Project management has developed an accelerated funding profile, calling for more initial dollars but no increase to the total of $456 million, which would allow completion of the APS a year earlier. That possibility has been communicated, and there has been some enthusiasm for it within the Department and Congress.

These next few months will be critical to the progress of the Advanced Photon Source. If the case for an accelerated funding schedule is made, perhaps the APS will have some chance of competing with next-generation facilities being constructed in Europe and Japan.

LETTERS OF INTENT

APS user programs are approaching an important date. May 1, 1990, has been set as the deadline for submission of experiment proposals in the form of Letters of Intent from prospective users, both Independent Investigators and Collaborative Access Teams. Those Letters of Intent that are approved will move on to the formal proposal stage. Finally, there will be a third stage, where a memorandum of understanding is signed cementing relationships between users and the Laboratory.

All those associated with the APS can view May 1 as that point in time when the variety and scope of research interests will come into clearer focus, and the APS's true potential will begin to take shape concurrent with its physical manifestation.