# Status of the Advanced Photon Source (APS) Linear Accelerator *

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*Abstract*

A 2856-MHz S-band, 450-MeV electron/positron linear accelerator is the first part of the injector for the Advanced Photon Source (APS) 7-GeV storage ring. Construction of the APS linac is currently nearing completion, and commissioning will begin in July 1993. The linac and its current status are discussed in this paper.

## I. Introduction

Electrons are accelerated to 200-MeV by the electron linac, and then impinge on a tungsten positron converter target. The resulting positrons are accelerated to 450 MeV in the positron linac and are accumulated in the positron accumulator ring prior to injection into the synchrotron. Positron energy is increased from 450 MeV to 7 GeV in the synchrotron before injection into the storage ring at final energy.

The injector portion of the electron linac consists of a thermionic gun, a single gap prebuncher, a constant impedance buncher with $v_p = 0.75c$, and a 3-meter-long constant gradient travelling wave accelerating structure. The prebuncher, buncher, and accelerating structure are powered by a single klystron. Rf power from a second klystron is transmitted to a SLED [1] cavity assembly. The SLED compresses the rf power in time, proportionally increasing the peak power. The shorter but higher peak power pulse is split four ways, powering the final four accelerating structures in the electron linac. A dipole magnet is installed at the end of the electron linac for energy optimization and analysis.

The 200-MeV beam from the electron linac is focussed down to a 3-mm spot by a set of triplet quadrupoles and it impinges on a 2 $X_0$ (7 mm) thick water-cooled tungsten target. A pulsed solenoidal coil just downstream of the target produces a 1.5 T field focussing the beam into the positron linac, where nine accelerating structures accelerate the positrons to 450 MeV. The first two accelerating structures are surrounded by solenoidal magnets for focussing and containment of the low energy beam, and the final seven have 24 FODO quadrupoles mounted around them. Steering magnets are positioned throughout the linac. The positron linac is powered by three klystrons and two SLEDs, as shown in Figure 2.

Lead and Heavimet shielding have been incorporated into the water-cooled target housing for protection of upstream and downstream equipment. Beam positioning on the target is aided by beam diagnostic readouts and by minimizing collected charge on a foil iris located in front of the tungsten target.

The linac beamline is shown in Figure 1, and some parameters are listed in Table 1.

Table 1
Electron and Positron Linac Beam Parameters.

| | $e^-$ Linac | $e^+$ Linac |
|---|---|---|
| Particle Type | $e^-$ | $e^+$ |
| Beam Energy | 200 MeV | 450 MeV |
| Pulse Rate | 48 pps | 48 pps |
| Pulse Length | 30 nsec | 30 nsec |
| Particles/Pulse | $3.125 \times 10^{11}$ | $1.563 \times 10^{9}$ |
| Beam Current | 1.7 A | 8 mA |
| Beam Power | 480 W | 5.4 W |
| Beam Emittance (mm-mrad) | $\leq 1.2$ | 6.6 |
| $(\Delta E/E)$ | $\pm 0.08$ | $\pm 0.01$ |
| # of Acc. Str. | 5 | 9 |

## II. RF System

### *A. High Power RF*

Klystron amplifiers (Thomson TH 2128) are powered by line type pulsed modulators which provide 100 MW peak power to the klystrons. Regulation is done with a command charge tetrode system and operates at a repetition rate of up to 60 Hz. Thirty MW of rf power at 2856 MHz is fed into the accelerating structures which produces an electric field gradient of about 20 MV/m. The modulators are discussed in more detail in another paper presented at this conference [2].

### *B. Low Level RF*

The 2856-MHz low level output of a highly stable master oscillator is amplified by a 10-W GaAs FET amplifier, and is then divided into two separately distributed signals. One of these signals is distributed to the five klystron drivers, and the other provides the reference to the VXI-based phase measurement system.

The klystron driver uses a preamplifier and a 400-W pulsed driver amplifier [3] which follows it. Both the

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preamplifier and the pulsed driver amplifier are based on bipolar transistor technology.

## III. Beam Diagnostics

Twelve beam position monitors (BPMs) [4], three wall current monitors, and eight fluorescent screens [5], measure the beam position and current in the APS linac. The gun current and pulse width are measured by a toroidal current monitor located just downstream of the electron gun. Stripline BPMs, shown schematically in Figure 3, measure the beam's position and intensity both horizontally and vertically with sensitivities of 1.805 $\pm$ 0.15dB/mm. The beam's relative position, spot size, and shape are measured by fluorescent screens. The video image is frame grabbed, processed, and displayed. The resulting image is accurate to approximately 600$\mu$m. Prototypes of these devices were successfully used to analyze beam characteristics in a pretest of the linac injector [6]. BPMs, fluorescent screens, as well as average current monitors are installed throughout the linac.

## IV. Readout and Controls

The linac control system uses the Experimental Physics and Industrial Control System (EPICS) tools which are being developed by the Controls and Computing group at APS/ANL and by the AT8-GTA groups at LANL [7]. Eight microprocessor-based Input/Output Controllers (IOCs) provide real-time control, monitoring, and data acquisition services to the linac equipment. Two IOCs accommodate the beamline equipment, including vacuum, magnets, cooling water, etc. Each of the five rf stations has a dedicated IOC which acquires its rf and diagnostic measurements at a 60-Hz rate. An eighth IOC handles the image processing requirements for the fluorescent screen cameras. The IOCs are connected to a common ethernet by which they can communicate with each other and with the Unix-based Operator Interface workstations (OPIs). Several tools are available on the OPIs to support data archiving, alarm management, interactive equipment control, and backup/restore of machine settings, and are described in Reference [7].

Beam diagnostics readout and rf phase and amplitude measurements have been integrated, together with the dedicated microprocessor-based IOCs mentioned above, into a common VXI based system. LANL [8] VXI modules were upgraded for faster pulse response and are used with ANL's trigger timing module, constituting the central part of the system. Rf phase is measured using two VXI modules, a downconverter, and a vector detector, plus conversion software which computes phase from the detected I and Q vectors. Measurements repeatable to $\pm$0.1 degree have been demonstrated after appropriate averaging.

## V. Conclusion

Installation of the APS linac began in earnest in October of 1992. The electron linac installation has been completed, the beamline is under vacuum, most of the rf power system is in place, and control systems are operational. The positron linac installation will be complete by July of 1993 so that commissioning can begin. Relevant safety documentation and startup procedures are being prepared and reviewed now to ensure a timely startup.

## VI. Acknowledgements

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## VII. References

[1] Z.D. Farkas, H.A. Hogg, G.A. Loew, and P.B. Wilson "SLED: A Method of Doubling SLAC's Energy," SLAC-PUB-1453, June 1974.

[2] Thomas J. Russell, "Noise Reduction Techniques Used on the High Power Klystron Modulators at Argonne National Laboratory," these proceedings.

[3] 400 Watt solid state amplifier originally manufactured by SGS Thomson (now MPD).

[4] Raymond Fuja and Youngjoo Chung, "The APS Linac Beam Position Monitors and Electronics," *Acc. Instr. Wkshp. Proc.*, Berkeley, CA, Oct. 1992.

[5] W. Berg and K. Ko, "Fluorescent Screens and Image Processing for the APS Linac Test Stand," ibid.

[6] W. Berg, R. Fuja, A. Grelick, G. Mavrogenes, A. Nassiri, T. Russell, W. Wesolowski, and M. White, "Beam Measurements of the ANL-APS Linac Injector Test Stand," *Linac Conf.*, Ottawa, Can. Aug. 1992

[7] McDowell, William P. , "Status and Design of the Advanced Photon Source Control System," these proceedings.

[8] C. Ziomek, "Accelerator RF Instrumentation Implemented with the VXIbus," *Proc. ATE & Instr. Conf.* January, 1991.

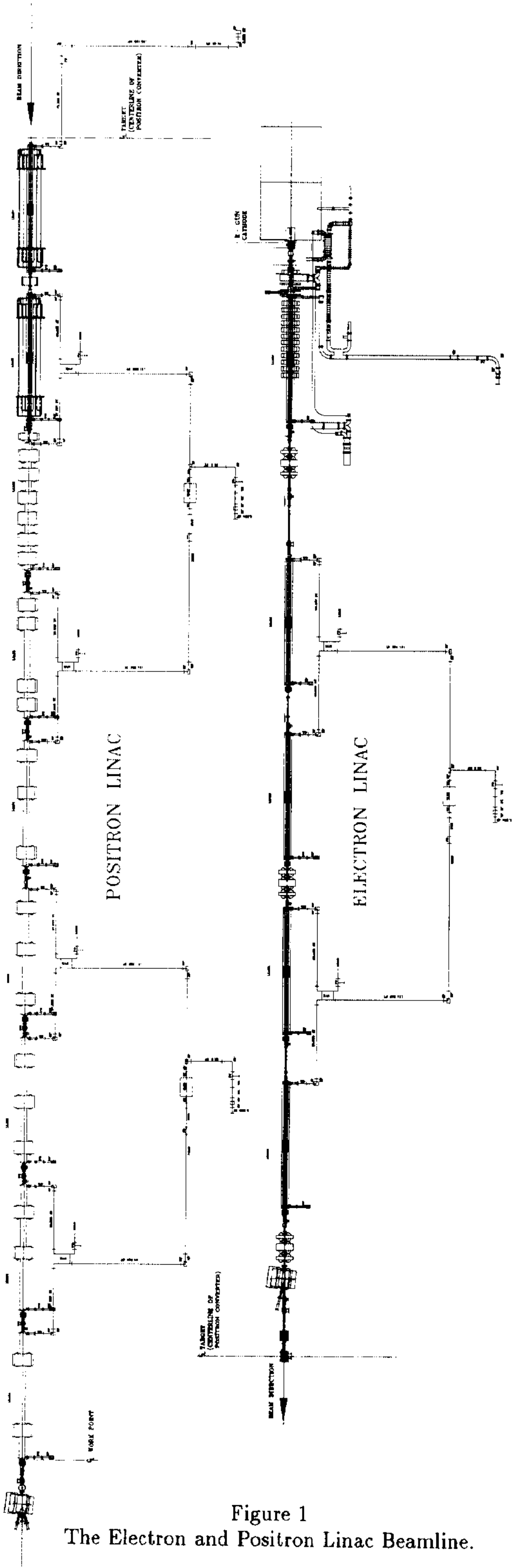



Figure 1
The Electron and Positron Linac Beamline.

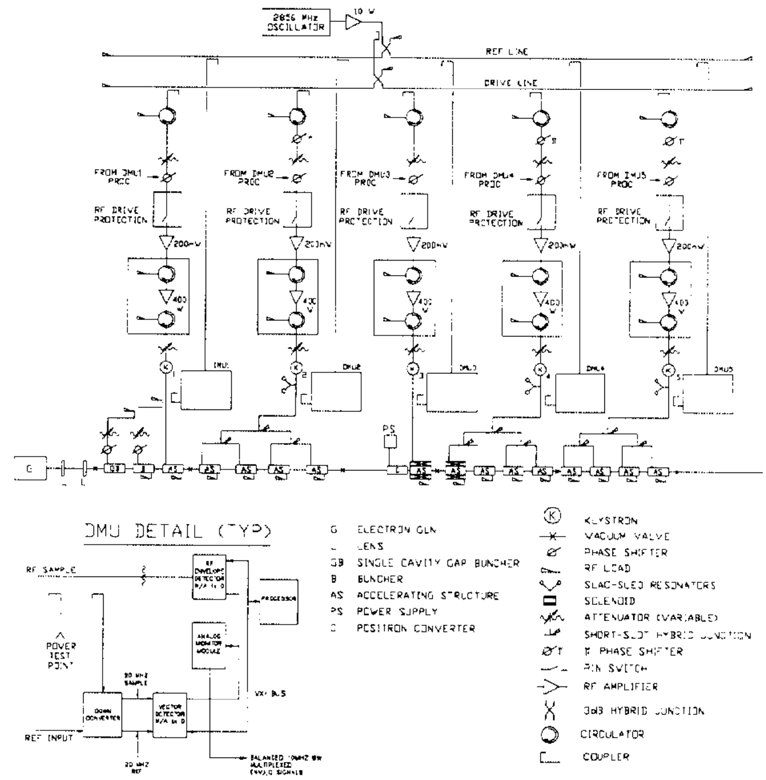
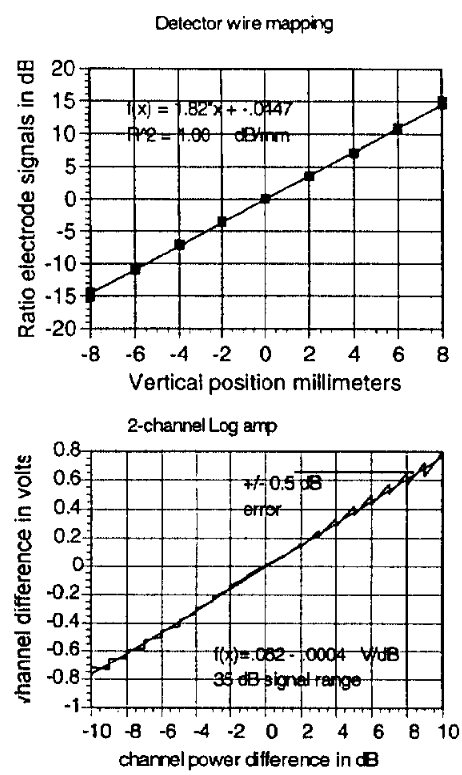



Figure 2
The Linac RF Circuit Diagram.




Overall sensitivity detector and electronics = 112 mV/mm
Resolution +/- 40 microns

Figure 3
The Beam Position Monitors (BPMs) allow a simple, accurate determination of the beam position.