PERFORMANCE OF THE ADVANCED PHOTON SOURCE (APS) LINEAR ACCELERATOR[*]

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Abstract

A 2856-MHz S-band, electron-positron linear accelerator (linac) is the injector and source of particles for the APS [1]. The linac is operated 24 hours per day, with 405-MeV electrons to support commissioning of the other APS accelerators, and with positrons or electrons to support linac studies. It produces electrons with energies up to 655 MeV or positrons with energies up to the design energy of 450 MeV.

I. INTRODUCTION

The design goal of the APS electron linac is to accelerate 30-nsec-long pulses containing 50 nC of electrons to an energy of 200 MeV. The beam is focused to a 3-mm diameter spot on a 7-mm-thick water-cooled tungsten target that serves as a positron converter. Pair produced positrons and electrons are refocused by a 1.5-T pulsed coil, and are directed into the positron linac where they are captured and accelerated to 450 MeV ± 1%. The design positron current is 8 mA. To date, 1.45 A of electrons were accelerated to 225 MeV at 30 Hz in the electron linac, and were focused to a $\leq$ 5-mm diameter spot on the target. The linac was able to accelerate 9 mA of positrons to 285 MeV within one week of the beginning of positron studies, and has since achieved a positron energy of 450 MeV with an energy spread less than ± 1.6%. Measured radiation levels near the linac are within DOE guidelines [2].

II. EQUIPMENT DESCRIPTION

Particles are accelerated in the linac by 14 SLAC-type accelerating structures, five in the electron linac and nine in the positron linac. The upstream accelerating structure in each part of the linac is directly powered by a 35-MW klystron, while the remaining 12 structures are powered in groups of four by a klystron and a SLED cavity assembly, as shown in Figure 1. Power to the klystrons is provided by 100-MW line-type modulators. Recent upgrades to the modulators led to improved performance and reliability, and are described elsewhere [3].

The individual timing of each of the five pulse modulators is optimized to gain maximum energy from the available rf power in each sector, and the timing of each of the three SLEDs is also individually optimized for maximum energy gain. The electron or positron beam is bent into the appropriate diagnostic line, and data on timing versus energy, interpreted from the beam position on a fluorescent screen, are taken and analyzed using sdds tools [4]. Timing is reoptimized after modulator upgrades and SLED retuning, and Figure 2 is an example of such a timing curve. Figure 3 is the diagnostic line at which the data were taken.

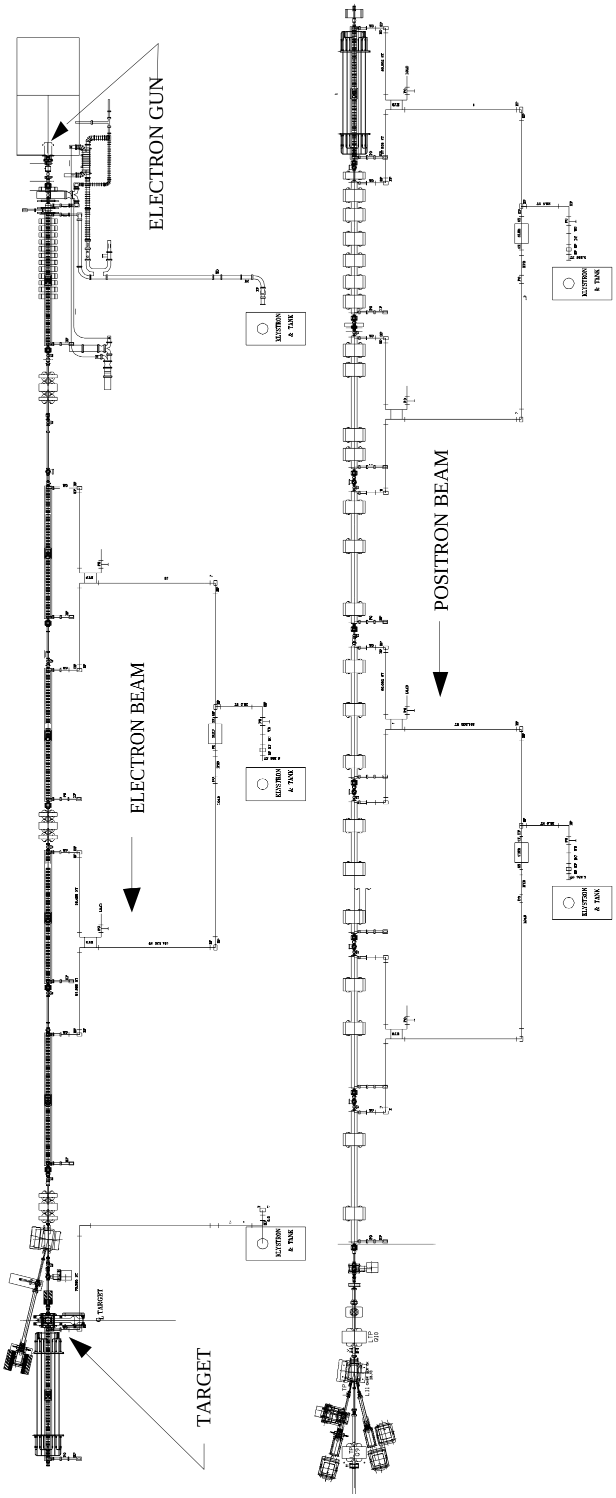

Figure 1: Overview of the electron and positron linacs.

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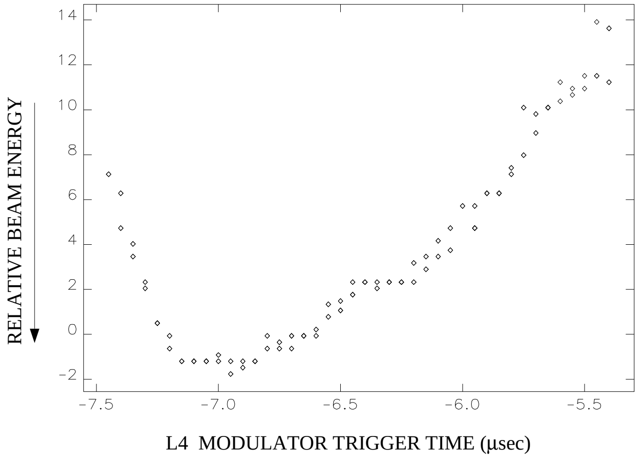


Figure 2: Modulator (and SLED) timing optimizations are performed for each sector to optimize use of the modulator pulse and thus achieve maximum energy gain. These modulator timing data were collected using sdds tools [2].

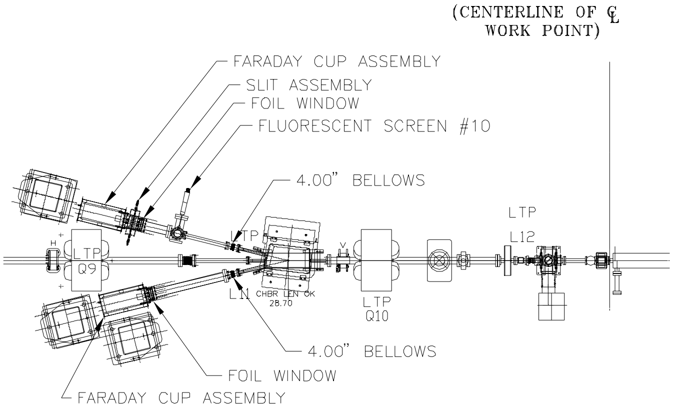


Figure 3: Positron linac diagnostic lines allow energy, energy spread, and phase optimization to be performed for electrons or positrons. Other beam parameters are also measured using information from equipment in this line.

A new beam position monitor (BPM) will be installed at the exit of the dipole magnet shown in Figure 3, and will allow continued development and eventual routine use of automated rf phase optimization programs.

The low-level rf system has functioned well for more than a year and is described elsewhere in these proceedings, along with the existing automatic rf phase control system that maintains constant phase (to within ± 2°) between the five klystrons [5].

Linac beam diagnostics include wall current monitors, BPMs [6], fluorescent screens [7], and loss monitors. The existing BPMs are unable to distinguish between positive and negative signals, so positron optimization must be done using BPMs in conjunction with other information. A new type of BPM currently under development will be able to make the distinction, and will facilitate positron tuning if successful [8]. Average current monitors are installed for the purpose of shutting down the linac in the unlikely event that the average electron current in either the electron linac or the positron linac becomes excessive. The quantity of each type of diagnostic in each section of the linac is listed in Table 1. The beam's microbunch length has been measured by backphasing, and also by using a 5th-harmonic rf cavity. Descriptions of the technique and the first results are found in [9].

Table 1: Linac Diagnostics.

Type	# in e- linac	# in e+ linac
average current mon.	2	2
wall current mon.	3	1
BPM	5	5
fluorescent screen	3	5
loss monitor	5	9
5th harmonic cavity	1	0

The linac is controlled by the Experimental Physics and Industrial Control System (EPICS) [10]. The system is extremely flexible and when combined with the sdds toolkit, provides a powerful environment for monitoring and control of the linac and its various systems. Figure 4 is an example of an EPICS control screen for the linac.

III. PERFORMANCE

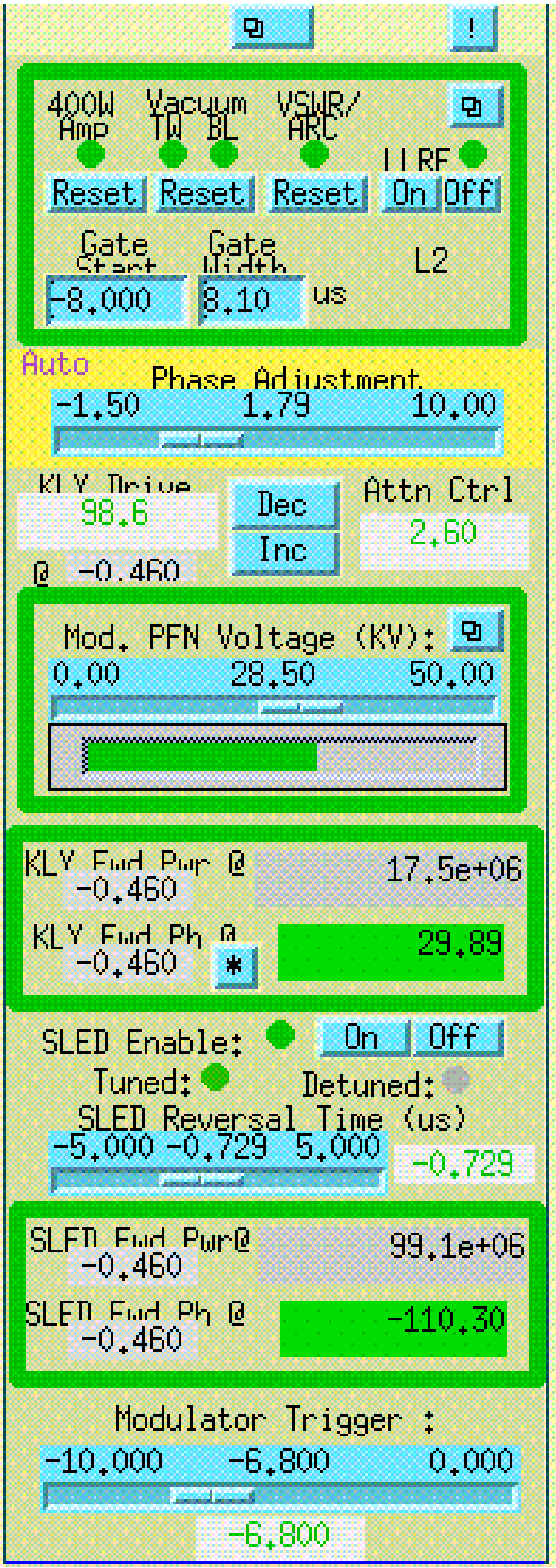
Table 2 lists a summary of the linac's performance to date.

Table 2: Linac Performance Summary.

	Design Goal	Achieved
Electron Linac		
Energy on Target	200 MeV	235 MeV
Pulse Length	30 ns	30 ns
Target Spot Size	φ ≤ 3 mm	φ ≤ 5 mm
Power on Target	480 W	225 W
Current on Target	1.7 A	1.45 A
Repetition Rate	48 pps at a 60-Hz rate	30 Hz
Maximum Energy	650 MeV	655 MeV
Energy Spread	± 8 %	≤ ± 8 %
Emittance	≤ 1.2 mm mrad	≤ 1.2 mm mrad
Positron Linac		
Output Energy	450 MeV	458 MeV
Output Current	8 mA	9 mA
Energy Spread	± 1 %	≤ ± 1.6 %

IV. SUMMARY

The APS linac has been operational for about a year, and has met most of its design goals. Considerable time was spent conditioning the high power rf equipment, however conditioning is now excellent for most purposes. The design goal for positron current at the design energy has not yet been



Gate Start -8.000

Gate Width 8.10 us

L2

Auto Phase Adjustment -1.50 1.79 10.00

KLY Drive 98.6 @ -0.460

Attn Ctrl 2.60

Mod. PFN Voltage (KV): 0.00 28.50 50.00

KLY Fwd Pwr @ -0.460 17.5e+06

KLY Fwd Ph @ -0.460 29.89

SLED Enable:

Tuned:

Detuned:

SLED Reversal Time (us) -5.000 -0.729 5.000 -0.729

SLED Fwd Pwr@ -0.460 99.1e+06

SLED Fwd Ph @ -0.460 -110.30

Modulator Trigger : -10.000 -6.800 0.000 -6.800

Figure 4: An example of a portion (20%) of the linac rf overview control screen. Rf power, timing, and phase information can be read out and modified from this screen. A limited set of faults can be reset directly, and a variety of "engineering screens" are accessible from pull down menus on this screen.

met. By the time rf conditioning permitted 450-MeV positron runs, the gun cathode performance had degraded significantly. The cathode is scheduled for replacement, and the design positron current at 450 MeV will most likely be achieved during the first shift with the new cathode. The positron focusing system as well as some possible improvements to it are discussed in [11].

The linac operates 24 hours per day to produce 405-MeV electrons for the purpose of commissioning the other APS accelerators. Positrons are used in linac and low energy transport line studies but, will soon be injected into the positron accumulator ring.

Acknowledgments

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