THE ADVANCED PHOTON SOURCE LINAC EXTENSION AREA BEAMLINE*

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Abstract

The Linac Extension Area at the Advanced Photon Source is a flexible beamline area for testing accelerator components and techniques. Driven by the Advanced Photon Source electron linac equipped with a photocathode RF electron gun, the Linac Extension Area houses a 12 m long beamline. The beamline is furnished with YAG screens, BPMs and a magnetic spectrometer to assist with characterization of beam emittance and energy spread. A 1.4 m long insertion in the middle of the beamline is provided for the installation of a device under test. The beamline is expected to be available soon for testing accelerator components and techniques using round and flat electron beams over an energy range 150–450 MeV. In the present work, we describe this beamline and summarise the main beam parameters.

INTRODUCTION

The Linac Extension Area (LEA) at the Advanced Photon Source (APS) is an electron beamline for the demonstration of accelerator technologies, instrumentation and techniques. The beamline was designed to transport round and flat electron beams over an energy range 150–450 MeV.

In the present work, we outline the parameters of the three electron beam sources to LEA. We outline the beamline hardware and lattice. We conclude with an outlook on accelerator technologies and techniques that could be tested using the LEA beamline.

ELECTRON SOURCES

The APS linac provides electron beams to the injector complex, including LEA. Three electron sources can be configured to deliver electron beams to LEA, in different charge configurations. These include: a photocathode (PC) radiofrequency (rf) gun, two thermionic cathode (TC) rf guns, and the Particle Accumulator Ring (PAR). Parameters of beams from different electron sources are summarised in Table 1.

Table 1: Parameters Of Beams From The Electron Guns And PAR

Parameter	Units	PC	TC	PAR
Charge per cycle	nC	0.3	1.0	20
Bunch charge	nC	0.3	0.007	20
Bunch length	ps	1	1	1000
Bunches per cycle	…	1	29	1
Bunch spacing	ns	…	0.35	…
Repetition rate	s^{-1}	6	30	1

Photocathode RF Gun

The PC gun is the principal electron source for LEA [1–6]. An Nd:Glass laser oscillator and amplifier provides ps laser pulses at 1053 nm wavelength [7]. The laser wavelength is frequency-doubled twice to 263 nm using second harmonic generation in beta barium borate crystals. The electron bunch charge from the PC gun is typically up to ~0.3 nC.

Thermionic Cathode RF Gun

Two TC guns are the principal injectors for the APS injector complex [8–11]. The 2856 MHz rf frequency TC guns are typically operated providing a train of electron bunches of ~1 nC total train charge, over a bunch train duration of ~10 ns.

Particle Accumulator Ring

One interesting feature of the APS accelerator complex stems from its original design as a positron accelerator chain. Hence the injectors include the Particle Accumulator Ring (PAR), which is operated as an electron beam damping and accumulator ring [12].

Electron beam from the TC gun would be accumulated in the PAR, before transporting the extracted beam to LEA. This represents an electron source for experiments at LEA with high electron bunch charge (≤ 20 nC), for applications or experiments where ~1 ps electron bunch durations are not required.

Interleaving Beam Operations

The APS linac and injectors principally support injection into the APS storage ring, including top-up operation of the storage ring. Typical top-up intervals at the APS storage ring are 1–2 min. The injectors have been configured to support interleaving of the electron sources between directing beam to the storage ring for top-up (few seconds per minute), and to LEA [13–15].

LINAC EXTENSION AREA BEAMLINE

The longitudinal positions of the LEA beamline components are summarised in Table 2. The principal magnetic elements are quadrupole magnets, horizontal and vertical

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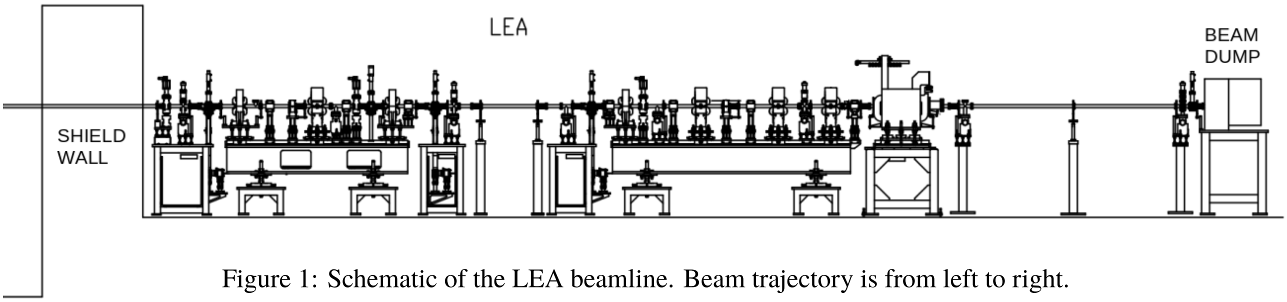

Figure 1: Schematic of the LEA beamline. Beam trajectory is from left to right.

Table 2: LEA Beamline Lattice

Element	Position s (m)	Length l (m)	Gradient (T m^{-1})
LE:GV1	0		…
LE:BPM1	0.464		…
LE:YAG1	0.578		…
LE:Q1	0.938	0.100	7.17
LE:SC1	1.318		
LE:CM1	1.623		…
LE:Q2	1.941	0.153	-7.67
LE:SC2	2.295		
LE:GV2	2.396		…
LE:Q3	2.863	0.100	7.78
LE:SC3	3.065		
LE:BPM2	3.275		…
LE:YAG2	3.358		…
LE:BPM3	5.253		…
LE:YAG3	5.330		…
LE:SC4	5.605		
LE:Q4	5.804	0.100	7.78
LE:GV3	6.011		
LE:SC5	6.405		
LE:Q5	6.779	0.153	-7.62
LE:CM2	7.024		…
LE:SC6	7.382		
LE:Q6	7.755	0.153	7.17
LE:Q7	8.417	0.153	-4.26
LE:SC7	8.691		
LE:BPM4	8.871		…
LE:SPECT	9.025		
LE:YAG4	13.538		…

corrector magnets, and the vertical bending magnet spectrometer. A beam absorber and lead electron beam dump is positioned at the downstream end of the beamline.

An elevation view of the beamline is illustrated in Fig. 1. Lattices for round and flat beam transport in interleaving operation of the LEA beamline were previously developed, including the operation of the spectrometer bending magnet [13]. The lattice simulated using elegant with the spectrometer de-energised (a drift), to the beam dump in the orbit plane of the beamline is summarised in Fig. 2 [16].

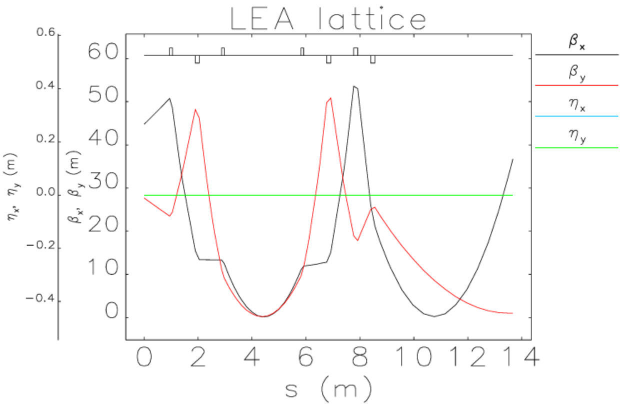

Figure 2: LEA lattice for beam transport to the beam dump. The lattice provides round beams at the insertion (4.3 m).

Hardware

A photograph of the installed hardware of the LEA electron beamline [17] is illustrated in Fig. 3.

Figure 3: Photograph of the installed LEA beamline.

OUTLOOK

The LEA beamline is installed to support accelerator physics and technology experiments. Opportunities for potential experiments using the installed hardware are outlined below.

Techniques for lattice optimisation and beam transport could be tested using the LEA beamline. This could include nonlinear or machine learning techniques.

The performance of materials for shielding gamma rays or neutrons could be evaluated using the LEA beamline.

Distributed beam loss monitors (in particular fibre-based loss monitors) are useful diagnostics in transport lines. The LEA beamline could be used to evaluate performance of loss monitors.

Several beam profile monitors are installed along the length of the LEA beamline. This presents an opportunity to evaluate the imaging performance of different scintillator materials.

SUMMARY

The LEA electron beamline at the APS is for the demonstration of accelerator technologies, instrumentation and techniques. The beamline was designed to transport round and flat electron beams over an energy range 150–450 MeV. With TC and PC electron guns and an electron storage ring as sources, a range of different potential experiments could be performed using the presently-installed LEA beamline hardware.

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