INTERLEAVING LATTICE DESIGN FOR APS LINAC*

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Abstract

The design of the lattice for the Advanced Photon Source (APS) injector linac suitable for the interleaving operation of the thermionic and photocathode rf electron guns is presented.

INTRODUCTION

The APS linac is part of the injector complex of the APS storage ring. The thermionic RF electron gun (RG) provides the electron beam that is accelerated through the linac, injected into the Particle Accumulator Ring (PAR), cooled, transferred to the Booster synchrotron, accelerated, and injected into the APS storage ring. The linac is also equipped with the state-of-the-art S-band photocathode RF electron gun (PCG) that serves as a backup to the RG. Three fast switching dipole magnets at the end of the linac (interleaving dipoles) direct the electron beam in and out of the PAR and into the Booster. Turning them off allows to bypass PAR and Booster and send electrons into the Linac Extension Area (LEA) tunnel which follows the APS linac. The existing beamline in the LEA is going to be repurposed for testing of small aperture apparatus and other beam physics experiments taking advantage of the PCG generated high brightness beam.

Typically, the beam generated from RG is used ~ 20 seconds every two minutes to support storage ring top-up operation. Fast switching (interleaving) between RG and PCG will allow operating LEA beamline during the rest of the two minutes. Because of the significantly different properties of beams produced by RG and PCG including beam energy, energy spread, bunch length, emittance and bunch charge, setting up one single lattice for the linac suitable for both beams is extremely challenging. In this paper we present a solution of this problem. Section 2 introduces optimum APS linac lattice for storage ring injection. Section 3 describes the optimum APS linac lattice for PCG and LEA experiments. A compromise interleaving lattice that conserves the high brightness of the PCG generated beam and maintains the high injection efficiency to PAR of the RG generated beam is described in Section 4.

APS LINAC LATTICE FOR INJECTION

Figure 1 shows the layout of the APS injector linac. It includes twelve S-band accelerating structures and an asymmetrical magnetic chicane containing four dipoles and two quadrupoles. One thermionic RF gun and one alpha magnet is used to inject a short train of electron micro bunches into the linac. (An identical spare set is also installed). The PCG is installed at the front end of the linac and equipped with one additional accelerating structure. Note that alpha magnet and chicane are redundant for the operation with the RG generated beam and therefore, chicane is only dedicated to compress PCG generated beam. Table 1 shows the main beam parameters.

Satisfying the requirement for injection into the PAR, APS linear accelerator have been operated with minimal beam loss through linear accelerator after filtering low energy electrons in the alpha magnet. Figure 2 shows lattice functions for APS linear accelerator. In order to prevent beam loss, beta functions though linear accelerator are kept below 25 m. Two dispersion bumps (one in the chicane and one in the beam transport line) are present in the horizontal plane. Due to large dispersion function and beta function in the region before PAR, horizontal RMS beam size is 3.5 mm and horizontal full aperture is 16 mm in this region. However, careful trajectory control in this region is achieved to prevent beam loss. Lattice functions at the end point are matched with PAR injection point.

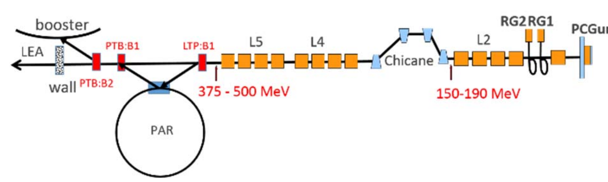

Figure 1: Layout of APS linear accelerator.

Table 1: Parameter for APS Linear Accelerator

Parameter	RG beam for Injection	PC beam for R&D
Energy	375 MeV	> 375 MeV
Emittance	15 um rad	1 um rad
Charge	1.6 nC	300 pC
Peak I	300 A	> 1 kA

APS LINAC LATTICE WITH PC GUN

The APS PC gun is a LCLS type gun [1] and is driven by a picosecond Nd:glass laser. The maximum field gradient in the gun cavity is 120 MV/m. High brightness with higher peak current (>1 kA) electron beam is produced by first increasing the electron beam energy to approximately 40-45 MeV in the first accelerating section (L1), giving energy chirp in the second accelerating section (L2) and finally rotating the particle distribution in the longitudinal phase space to reduce the bunch length via an asymmetric

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chicane. Accelerator sections (L4 and L5) located after chicane are adjusted to minimize the energy spread and obtain the desired final energy.

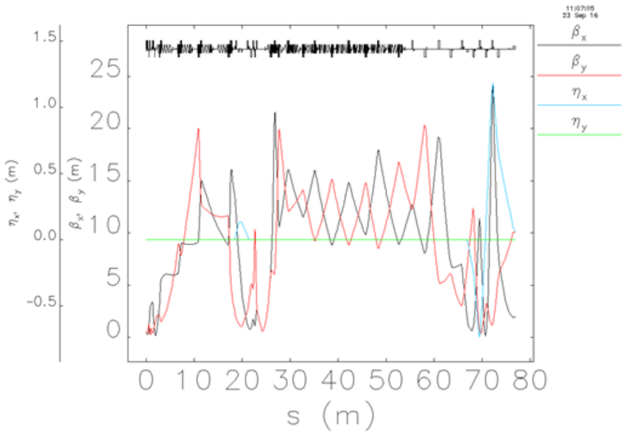

Figure 2: Lattice functions for APS injector linac for beam injection into the PAR.

The chicane in APS linac is a highly flexible bunch compressor with capability to switch from symmetric to asymmetric configuration. The advantage of asymmetric chicane is less emittance growth by CSR effect from last dipole due to weaker third and fourth dipoles than the first and second dipoles. However, dispersion function after the asymmetric chicane should be closed by using two quadrupoles within the chicane system. Based on the previous study [2], asymmetric chicane parameters are chosen in the lattice design.

Figure 3 shows lattice functions though APS linac to experiment area. Initial lattice functions are obtained from the simulation of the photo-injector using ASTRA [3]. Transverse matching conditions are to maintain small beta functions in the linac for transverse wakefield control, to minimize horizontal beta in the fourth dipole of the chicane for reducing CSR effect, and to match proper diagnostics condition in emittance measurement section. Vertical dispersion bump is present in order to transport beam into the upper level LEA from APS linac. Matching quadrupoles in beam transport line is performed to provide flexible beam focusing at the center of experimental area ranging from a tightly focused round beam to a flat beam.

INTERLEAVING LATTICE

It is challengeable to operate two different beams (different initial beam energy, Twiss parameters, emittance, charge, etc.) in an interleaving fashion. Critical parameters for interleaving operation are introduced in Table 2. Note that interleaving dipoles (shown by red boxes in Fig.1) and alpha magnets are alternating for RG and PCG beam. Longitudinal matching involves adjusting the phase and voltage of L2 for PCG beam to obtain the desired current and energy after the chicane, as well as to match with RG energy at the chicane location. Then L4 and L5 are adjusted to minimize the energy spread and obtain the desired final energy for both beams.

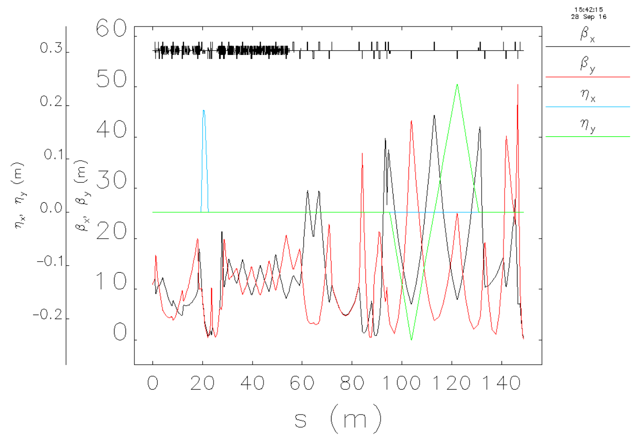

Figure 3: Lattice functions along APS LINAC and LEA optimized for PCG.

Following longitudinal matching, transverse matching is done for both beams. Detailed layout up to chicane system and energy ratio between PCG beam and RG2 beam are shown in Figure 4. The strategy of transverse matching is as follows: (1) lattice optimization for RG generated beam, and then setting these quadrupole values for PCG beam with energy scaling; (2) lattice optimization for PCG generated beam using two dedicated quadrupoles (two red bars in Fig.4) to keep low beta function; (3) PC beam optimization using Q11 to minimize horizontal beta function, and using the four quadrupoles (4Qs in the figure) for matching diagnostics condition for emittance measurement; (4) RG beam tuning with four dedicated quadrupoles (black bars in the Figure 4) to match to the same lattice functions after chicane. Finally, the lattice functions for both RG and PC beams becomes the same after the matching point, since the beam energy and lattice functions at matching point after chicane are same. Figure 5 shows lattice functions for both beams up to matching point. All constraint conditions for the matching are fully satisfied and lattice functions are closed to each dedicated optimum values.

Table 2: Parameter for Initial RG and PC Beams

Parameter	RG beam	PC beam
Energy	2.5 MeV	43 MeV
β_x / β_y	0.53 / 0.53	11 / 11
α_x / α_y	0.83 / 0.83	-0.6 / -0.6
η_x / η_y	0 / 0	0 / 0

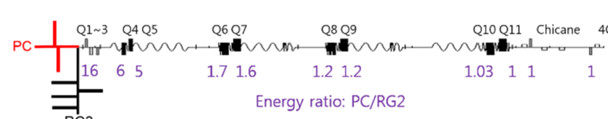

Figure 4: Beamline layout from gun to diagnostic stations downstream of the chicane.

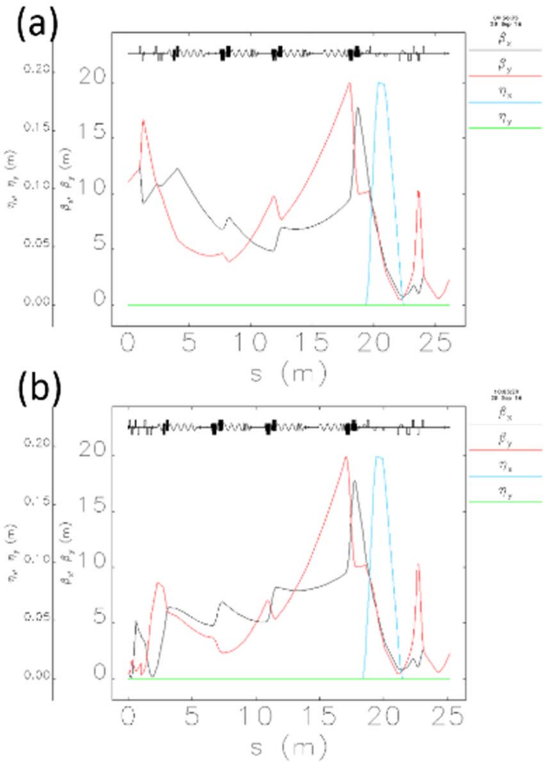

Figure 5: Lattice functions for both PCG (a) and RG (b) beams in interleaving operation.

CONCLUSION

In this paper, we described the lattice design for APS injector linac in support of interleaving operation of the thermionic RF electron gun and photochathode RF gun. In spite of significant differences of the original beams, an excellent compromise was found allowing efficient injection of the high charge RG generated beam into Particle Accumulator Ring and efficient transport of the high brightness PCG generated beam to the experimental beamline in the linac extension area for testing of small aperture apparatus and other beam physics experiments. As a future work, we will demonstrate interleaving lattice experimentally enabling the maximum usage of the APS injector linac.

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