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Optimizing the Injection Straight of PEP II Asymmetric B Factory at SLAC*

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ABSTRACT

The asymmetric energy PEP II B Factory proposed as an upgrade of PEP at the Stanford Linear Accelerator Center requires both a powerful low emittance source of e^-e^+ and a very reliable and efficient injection system. The SLC linac fulfills the source requirement very well. We describe here the optimization of the optics of the injection straight to insure reliable and efficient injection.

1. OVERVIEW

The power of the SLC linac, as a source for both electrons and positrons, was demonstrated in the conceptual design report (CDR) [1] (also see Table 1). A brief overview of the whole injection system is given in Reference [2]. Figure 1 is a schematic of the system. One can divide the injection system into two main parts. The first is the extraction of e^-e^+ from the linac and their bypass lines leading to and matching into the existing NIT and SIT lines used in PEP. The second is the injection straight, its optics and various components required for injection and matching into the main rings (HER, LER). The latter is the subject of this paper.

Figure 2 is a schematic of the injection straight. It illustrates the paths of the circulating and injected beams during injection.

The injected beam downstream of the end of NIT/SIT passes through a thin window which separates the high vacuum of the B Factory rings from the lower vacuum sufficient for the injection line and the linac. It approaches the Lambertson septum in a plane parallel to the horizontal *(x-z)* plane of the ring and makes an angle of ≅11 mrad with the *z*-axis. It is bent *horizontally* by the Lambertson into the vertical *(y-z)* plane of the circulating beam. The first half of the central split quad bends it down and the current sheet septum corrects its angle such that it exits the septum parallel to the central trajectory of the circulating beam. The second half of the split quad causes it to execute betatron oscillations around the circulating beam.

TABLE 1.
Selected B Factory injection parameters.

Beam energy	
High-energy ring (HER)	9 [range: 8–10] [GeV]
Low-energy ring (LER)	3.1 [range: 2.8–4] [GeV]
Beam current	
High-energy ring (HER)	1.48/6777 [A/10^{10} e^-]
Low-energy ring (LER)	2.14/9799 [A/10^{10} e^+]
Particles per bunch	
High-energy ring (HER)	4.1 [10^{10} e^-]
Low-energy ring (LER)	5.9 [10^{10} e^+]
Linac repetition rate	60 or 120 [pps]
Linac current	0.4–2 [10^{10} $e^{\pm}$/pulse][a]
Invariant linac emittance	5×10^{-5} [m•rad]
Normal filling time	
Topping-off (80-100%)	3 [min]
Filling time (0-100%)	6 [min]
Revolution period	7.336 [μs]
Harmonic number	3492
Number of bunches[b]	1746–5%=1658
Vertical damping time	
HER	38 [ms]
LER, with wigglers	37 [ms]
LER, without wigglers	68 [ms]
Nominal beam emittance	
HER, horizontal/vertical	48/1.9 [nm•rad][c]
LER, horizontal/vertical	96/3.8 [nm•rad][c]

[a]Assuming 75% filling efficiency and 1×10^{10} particles/pulse during filling 0-100%, 5×10^9 during topping. The SLC routinely delivers 2.5×10^{10} $e^{\pm}$ per linac pulse.
[b]For filling, the rings are divided into nine equal zones. A 5% gap leaves one zone partially unfilled.
[c]Unnormalized, or geometrical, values.

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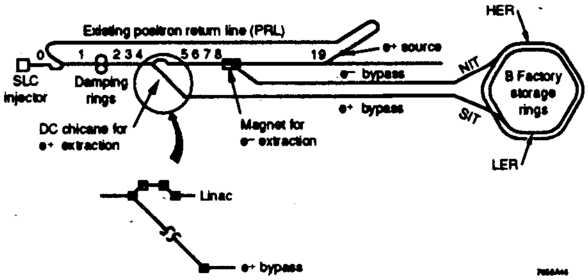

Figure 1. Schematic of the B Factory $e^{\pm}$ injection system, based on use of the SLC linac with bypass lines. The numbers along the linac indicate the location (not to scale) of each sector. Each of the 30 sectors is 100 m long.

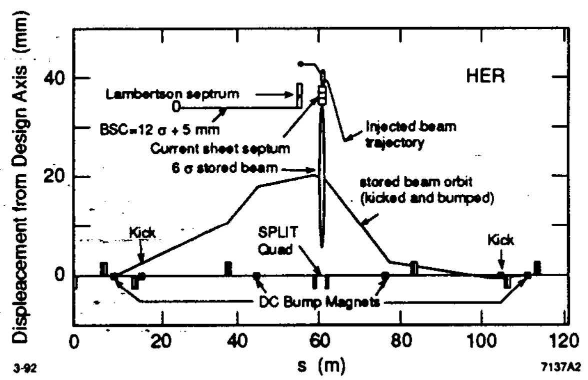

Figure 2. Schematic of injection straight. Paths of both circulating and injected beam are shown in the vertical plane during injection.

The main optics consists of 5 quads forming a $-I$ transformer with mirror symmetry around the center of the middle split quad. The circulating beam is bumped nearer to the current sheet septum using two identical kickers in mirror symmetry and 180° apart in phase, insuring a closed kick, and two pairs of DC magnets. The total bump needed is shared almost equally between the kickers and the DC magnets. In addition to reducing the kick required from the kickers, the closed bump produced by the DC magnets can change the angle of the circulating beam at the injection point. A proper choice of this angle can reduce the deflection required from the current sheet septum considerably.

2. OPTIMIZATION

To achieve reliability and efficiency, we used the experience gained with PEP I injection and made comparative studies of several possible injection schemes. The main features of the final scheme are listed below, each with a brief description of its advantages.

- Vertical injection: This reduces the parasitic crossing forces [3] acting on the injected beam which can lead to its blowup and loss. In addition, the absence of dispersion in the vertical plane eliminates energy related displacement in the arcs that can cause the off energy particles of the injected beam to miss the masks protecting the detector during injection.
- Conservative beam stay clear (BSC) for the circulating beam such that the injection straight does not restrict the dynamic acceptance of the main rings. We used the worst case fully-coupled emittance for calculating the beam σ, and the following BSCs:
  - ◊ $\geq 12\sigma + 5$ mm for stored beam
  - ◊ $\geq 10\sigma$ after the DC bump
  - ◊ $\geq 6\sigma$ after the total bump (DC + kickers)
- Maximum phase space available for injection: The current sheet septum is thin (1 mm) and is placed inside the main vacuum, which avoids phase space losses resulting from the septum and beam pipe wall thicknesses.
- Minimum chromatic effects: The chromatic func- tions [4]

$$A = W\sin(\theta) = \frac{d\alpha}{d\delta} - \alpha\frac{(d\beta)/\beta}{d\delta} \tag{1}$$

$$B = W\cos(\theta) = \frac{(d\beta)/\beta}{d\delta} \tag{2}$$

are minimized at the point of injection so that the phase ellipses for different momenta are made to overlap sufficiently to accept off--momentum injected particles [see Figure 3(a) and (b)]. The effect of the uncorrected chromatic functions A and B which is illustrated in Figure 3(b) can be understood qualitatively as follows: α determines the orientation of the ellipse in the phase space plane, and σ_y, $\sigma_{y'}$, are proportional to $\sqrt{\beta_y}$, $1/(\sqrt{\beta_y})$, respectively. Hence β affects the shape of the ellipse. Changes in α and β with momentum lead to a rotation of the phase space ellipse and a change in its shape.

- Minimum emittance growth due to multiple scattering at the window mentioned above: Multiple scattering contributes to $\sigma_{y'}$; therefore the optics of the injection line is arranged such that the phase ellipse at the window is upright and β is small (small σ_y, large $\sigma_{y'}$). β is controlled after the window to give the optimum β value at the injection septum.

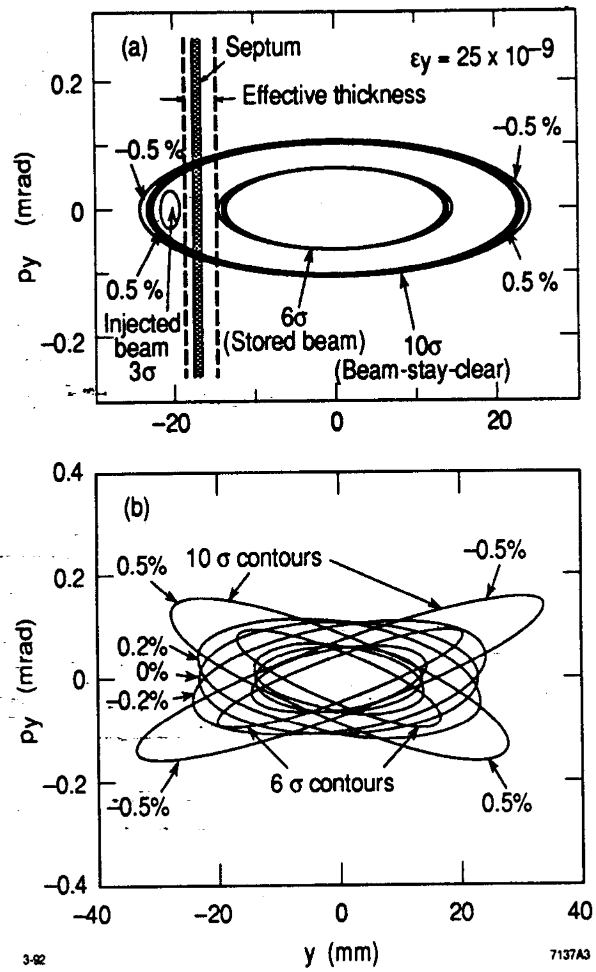

Figure 3. (a) Phase space diagram of injection acceptance for HER after chromatic correction. (b) Phase space diagram of injection acceptance for HER before chromatic correction.

- Low kicker voltages and low currents required for the current sheet septa: Both of these features increase the reliability of these components—particularly the kickers, which should track very well, insuring a closed bump. The tracking is further insured by driving the two

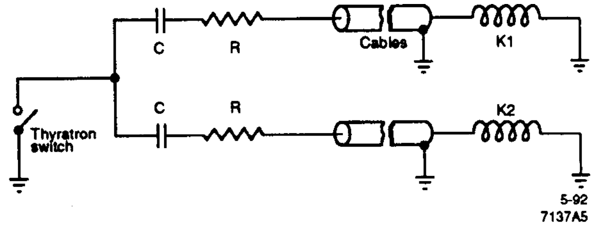

Figure 4. Schematic of the kickers drive

identical kickers in parallel from a single switch, as shown in Fig. 4. The critically damped circuits of the two kickers can be easily tuned for "identical" pulse shapes under typical running conditions.

3. CONCLUSIONS

•Chromatic corrections are crucial for obtaining an adequate injection phase space.

- Low kickers voltage and septa currents improve the reliability and reduce the frequency of maintenance; hence they increase the injection efficiency.
- Multiple scattering can increase the emittance of the injected beam substantially, resulting in injection efficiency loss; its effects should be minimized.
- Good kicker tracking is important, particularly for the case of multibunch operation.

REFERENCES

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