AN ALTERNATIVE LATTICE FOR THE SPALLATION NEUTRON SOURCE ACCUMULATOR RING*

C. J. Gardner†, Y. Y. Lee, N. Tsoupas, J. Wei, BNL, Upton, NY 11973, USA

Abstract

As a key component of the Spallation Neutron Source (SNS) Project, the Accumulator Ring will collect the proton beam from the SNS LINAC at an intensity of 2×10^{14} per pulse at 60 Hz for a total power of 2 MW, exceeding present performance value of existing facilities. Requirements of minimum beam loss for hands-on maintenance and flexibility for future upgrade are essential for the lattice design. In this paper, we study an alternative lattice emphasizing various injection schemes and flexibility for future upgrade. Working points, sextupole families for chromaticity control, and alternate extraction schemes are also considered.

1 THE NOMINAL LATTICE

The nominal lattice [1, 2] for the SNS Accumulator Ring consists of four superperiods, each containing a 90° arc and a long straight section. The arc consists of four identical 8-meter-long FODO cells, each cell containing two 11.25° bends and having a horizontal betatron phase advance of $\pi/2$. The arc therefore has unit transfer matrix in the horizontal plane, ensuring zero dispersion in the long straights. Two identical 11.586-meter-long FODO cells form each of the four long straights which house injection, collimation, rf cavities, and extraction systems, respectively. The horizontal and vertical tunes of the nominal lattice were originally taken to be $Q_H = 5.82$ and $Q_V = 5.80$ with a vertical phase advance of 2π in each arc. However, in order to minimize transverse coupling, a "split-tune" option with $Q_H = 5.82$ and $Q_V = 4.80$ has been considered. Here the vertical tune is lowered one unit by reducing the vertical phase advance in each arc to $3\pi/2$ (67.5° per cell). This option has the added advantage that it reduces the β_{max}/β_{min} ratio (from 13.6 to 7.3). The lattice functions for the split-tune case are shown in Fig. 1 where the plot runs from the center of one arc to the center of the next. The drift regions of the long straights in the nominal lattice are 5.293 m long (with 0.5 m quadrupoles). These can accommodate the necessary injection, collimation, rf, and extraction elements. Fig. 2 shows the nominal charge-exchange injection scheme [3, 2]. Here the three bends produce a fixed injection bump which allows the chopped H^- beam from the Linac to be injected through a stripping foil in the central 3 kG bend. The 8 fast kickers (shown in green) allow for horizontal and vertical transverse painting as some 1225 turns are accumulated.

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† Email: cgardner@bnl.gov

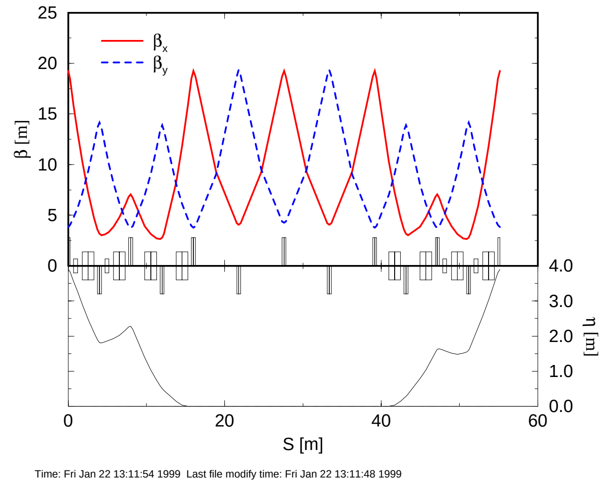

Figure 1: Split-tune FODO lattice.

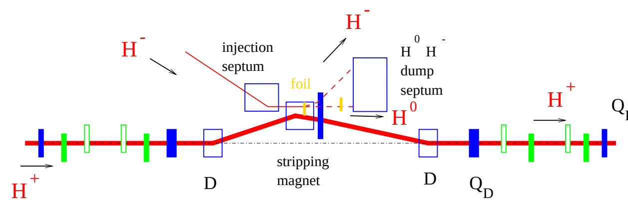

Figure 2: Foil injection in nominal FODO lattice.

2 DOUBLET/FODO HYBRID LATTICE

One of the key issues of the ring design is flexibility for future upgrade. Of particular interest is the ability to accommodate H^- injection with laser-undulator stripping [4, 5] should this become a viable option in the future. With this in mind, we have been studying the benefit of an alternative lattice, the so-called hybrid lattice, which has the same FODO arcs as the nominal lattice but has a doublet structure in the straights. The beta functions and dispersion for such a lattice are plotted in Fig. 3. Here the tunes are split ($Q_H = 5.82, Q_V = 4.80$) and the vertical phase advance in the arcs has been reduced to $55.8°$ per cell to minimize the beta function mismatch between the Doublet and FODO cells; the circumference is the same as that of the nominal lattice. The strength of the doublet quadrupoles is approximately three times that of the FODO quadrupoles in the nominal lattice straights. Comparing with Fig. 1 we see that the maximum beta is only slightly larger (21 versus 19.4 m). The doublet structure opens up 9.086 m drifts on either side of the central triplet. (The quadrupoles are 0.5 m long and the spacing within the doublets and triplet is 0.5 m.) If need be, these can be made longer while keeping the length of the arcs fixed. Fig. 4 shows the effect of adding length ΔL to the drifts. An important figure-of-merit here is the β_{max}/β_{min} ratio, which shows only small variation over the range of ± 4 m. We are currently study-

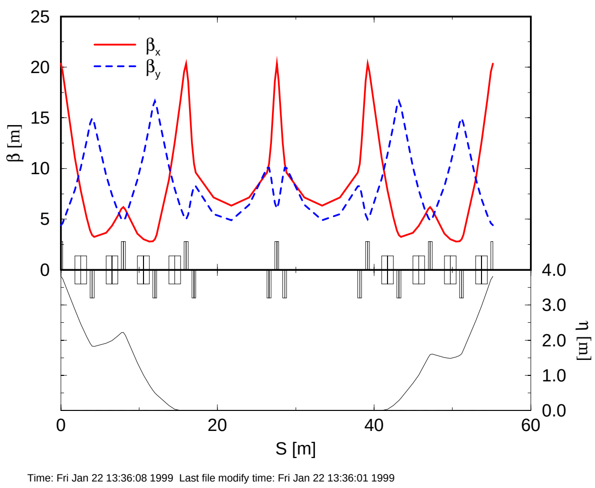

Figure 3: Doublet/FODO hybrid lattice.

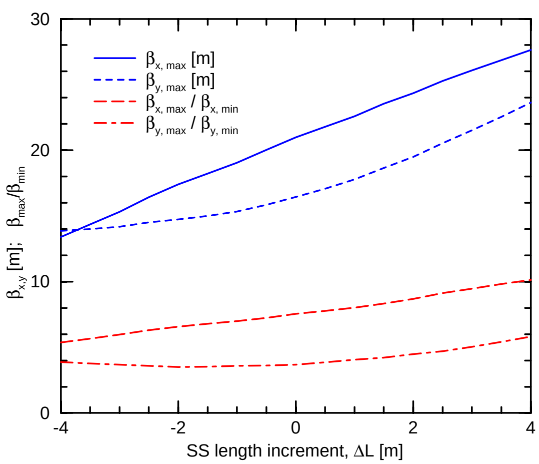

Figure 4: Variation of hybrid lattice parameters with ΔL.

ing the relative sensitivity of the hybrid lattice to random and systematic magnetic errors and are developing a correction scheme similar to that of the nominal lattice [6].

3 ALTERNATIVE INJECTION SCHEMES

The long drifts of the hybrid lattice provide the necessary space for a future laser-undulator charge-exchange injection scheme [4, 5] such as the one depicted in Fig. 5. Possible foil injection schemes that would fit in the same space are shown in Figures 6 and 7. The scheme of Fig. 6 is the same as that of the nominal lattice except that the beams emerging from the foil must pass through a triplet instead of a single horizontally focusing quadrupole. Here one must be careful that any excited H^0 beam emerging from the foil does not pass through fields greater than 2.5 kG in the triplet. (Keeping the field below 2.5 kG ensures that H^0 atoms with principle quantum numbers of $n = 4$ or less will survive the field [3].) In both the nominal scheme and that of Fig. 6, the 8 fast kickers (shown in green) produce a closed orbit bump (used for transverse painting) that is off-center in the central quadrupoles of the injection straight. This couples the injection setup with the tune of the lattice, which, although not a problem in principle, makes tuning more complicated in practice. Complete decoupling can be achieved by housing the entire injection scheme in one drift space as shown in Fig. 7. The magnitude of the kicks required in this case is 12 milliradians, twice that of the nominal scheme.

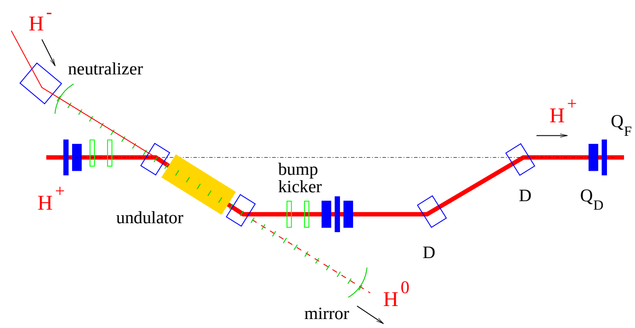

Figure 5: Doublet straight with laser-undulator injection.

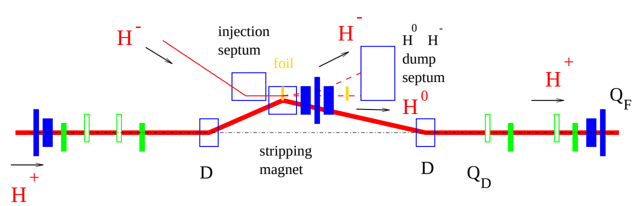

Figure 6: Doublet straight with foil injection.

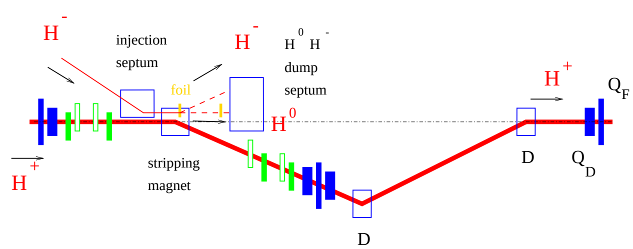

Figure 7: Doublet straight with decoupled injection.

In all of the injection schemes considered, the bending magnets break the four-fold symmetry of the ring. In the nominal scheme, where the bend angles are small (less than $2.4°$), a small amount of dispersion (0.3 m) is introduced in the long straights and there is a small perturbation (0.5 m) of the beta functions. The same is true of the scheme in Fig. 6. However, for the laser-undulator scheme, where the bends may be as large as $8.5°$, and for the decoupled scheme, where the central bend is $4.9°$, the perturbation of the symmetry is more severe. (For the decoupled scheme, a dispersion of 0.7 m is introduced in the long straights.)

4 EXTRACTION

The extraction scheme of the nominal lattice [2] is shown in Fig. 8. Here the fast kickers provide a vertical kick that allows the beam to clear a Lambertson magnetic septum. The Lambertson magnet deflects the beam by $15.5°$ with a field of about 5 kG, bringing the beam into the Ring-to-Beam-Target transport line. A possible extraction scheme for the hybrid lattice is shown in Fig. 9. Here the kickers are located close to the central triplet so that the effect of the lattice tune on the extraction setup is minimal.

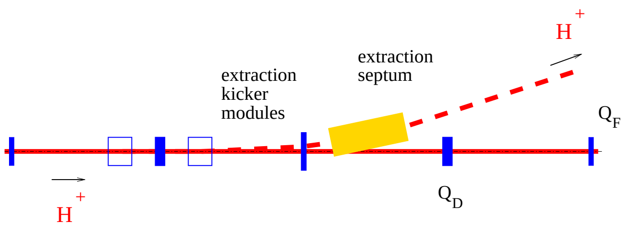

Figure 8: Extraction scheme for the nominal lattice.

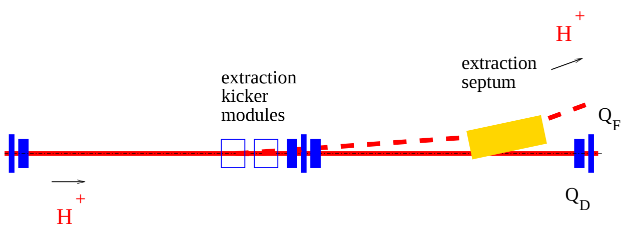

Figure 9: Extraction scheme for the hybrid lattice.

5 SEXTUPOLE OFF-MOMENTUM OPTICS MATCHING

In recent months, we have been studying the potential benefit of arc sextupoles in minimizing off-momentum optics mismatch and improving off-momentum dynamic acceptance [7]. Using 16 sextupoles of moderate strength (3 kG at 10 cm) grouped in 4 families, the amplitude of the off-momentum beta wave can be reduced from $\pm 12\%$ to less than $\pm 3\%$; this is shown in Fig. 10. Consequently, the off-momentum dynamic aperture can be increased by as much as 30%. The chromatic tune variation can be adjusted as desired across the entire range of beam momentum. Without enhancing the nonlinear chromaticity, the linear chromaticity can be either reduced or enhanced for tune spread optimization and possible instability damping.

6 CONCLUSIONS

Although the nominal lattice has a simple FODO structure that allows for considerable flexiblity in tuning, it does not have the long drift spaces required for the laser-undulator charge-exchange injection schemes which may become a reality in the future. The hybrid lattice considered here employs doublets to open up the necessary dirft spaces in the long straights. Both the laser-undulator and foil injection schemes can then be accommodated. The long drifts can also possibly accommodate the entire dynamic injection bump so that injection painting and lattice tuning are decoupled. Furthermore, the long drifts maximize the flexibility of the collimation device arrangement [7]. The acceptance of the hybrid lattice is comparable to that of the nominal lattice, but sensitivity to magnet errors remains to be examined.

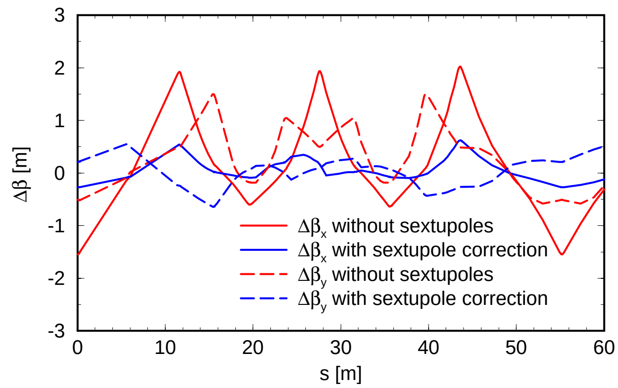

Figure 10: Beta-wave correction.

7 ACKNOWLEDGEMENTS

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