UPDATE ON THE ILC DR ALTERNATIVE LATTICE DESIGN

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Abstract

In order to reduce the cost for ILC damping rings, an alternative lattice which is different from the baseline configuration design has been designed previously with modified FODO arc cells, and the total quadrupole and sextupole number has been reduced largely, compared with the baseline design. At the same time, to decrease the total cost involved in constructing access shafts needed to supply power, cryogenics etc. for the wigglers and other systems, the number of wiggler sections is decreased from 8 to 4, and further to 2. However, the momentum compaction of this lattice can not be tuned freely. In this paper, a new ILC damping ring lattice design with a variable momentum compaction will be presented, followed by the single particle dynamics associated studies.

INTRODUCTION

The International Linear Collider (ILC) has just finished its reference design report and entered into the engineering design phase. For damping rings, there will be one electron ring and one positron ring placed in a shared tunnel around the interaction region of ILC. The beam energy is dedicated to be 5 GeV and the circumference is around 6.7 km. The 650 MHz RF cavity will be used to provide a RF voltage of ~24 MV, with the natural bunch length selected as 9 mm.

Regarding the ILC alternative damping ring design [1], its study was initiated at the Institute of High Energy Physics (IHEP, Beijing) from March 2006. At first, the FODO arc cell was used to replace the TME arc cell in the arc section, with the aim to use less quadrupoles and sextupoles. Then it was thought that the number of access shafts needed to supply power, cryogenics etc. for the wigglers and other systems could be decreased from 8 to 4, further to 2. So the number of wiggler sections in the FODO damping ring design has been decreased from 8 to 2, also with the aim to decrease the total cost of the damping ring. This lattice design has been optimized with two kinds of momentum compactions: 2×10^{-4} and 4×10^{-4}, to meet the requirement from the instability threshold estimation. The dynamic apertures of the alternative damping ring lattice with two momentum compaction cases are large enough to accept the positron beam with large emittance and large energy spread.

In order to get a damping ring design with variable momentum compaction, the whole FODO damping ring lattice has been studied and re-designed, including the arc cell, the dispersion suppressor, and other sections. The new ILC damping ring alternative lattice design has a momentum compaction which can be tuned in the range $2\times10^{-4} \sim 4\times10^{-4}$, by only changing the power supply of the quadrupoles. In the following we will present this new design and the single particle dynamics associated studies.

LINEAR LATTICE DESIGN

In order to get proper horizontal dispersion function and beta functions at the sextupole location in one arc cell, suitable maximum beta function (less than 55 m) in the arc section, and two kinds of phase advance for two momentum compaction cases, we scan the following parameters: the total arc cell number between 100 and 240; the arc cell length between 20 m and 40 m; the short drift length in one arc cell between 1 m and 3 m, according to Equation 1 and Equation 2.

$$\beta^{\pm} = \frac{L_P(1 \pm \sin\frac{\mu}{2})}{\sin\mu} \qquad (1)$$

$$D^{\pm} = \frac{L_P\phi(1 \pm \frac{1}{2}\sin\frac{\mu}{2})}{4\sin^2\frac{\mu}{2}} \qquad (2)$$

where β^+ and β^- are the maximum and minimum value of the beta functions, D^+ and D^- are the maximum and minimum value of the horizontal dispersion function, L_P is the length of the cell, μ is the phase advance of the cell, and Φ is the bending angle in one arc cell.

Finally, we select the arc cell length to be 29.4 m, and the arc cell number to be 184. The 72/72 degree and 90/90 degree arc cells are used in the cases of momentum compaction as 2×10^{-4} and 4×10^{-4} respectively. First we will introduce the design of the high momentum compaction case. The lattice functions in an arc cell are shown in Figure. 1.

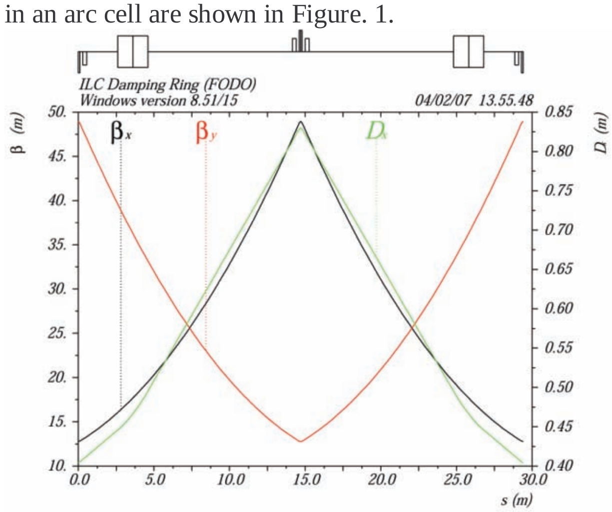

Figure 1: Lattice functions in an arc cell.

The design of dispersion suppressors is also different from the previous design. With the aim to have undisturbed TWISS parameters in the dispersion suppressor, based on Equation 3 and Equation 4, we add one arc cell after the last standard arc cell and modify the bending angle of these two cells according to the phase advance, as shown in Figure. 2.

$$\varphi_1 = \varphi \cdot \left(1 - \frac{1}{4\sin^2 \frac{\mu}{2}} \right) \quad (3)$$

$$\varphi_2 = \frac{\varphi}{4\sin^2 \frac{\mu}{2}} \quad (4)$$

Here φ is the bending angle of one standard arc cell, φ_1 and φ_2 are the bending angles of the modified arc cells at side $D \neq 0$ and $D = 0$, respectively.

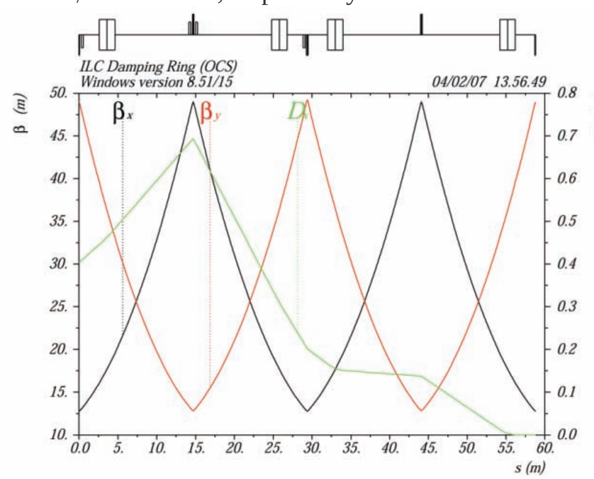

Figure 2: Lattice functions in a dispersion suppressor.

The wiggler/RF cavity sections are kept the same as the original design. The injection and extraction optics are designed to accommodate either of two different types of kickers that are studied at Fermilab: a pulsed kicker system with 6 ns rise time (and longer fall time) and a Fourier kicker [2].

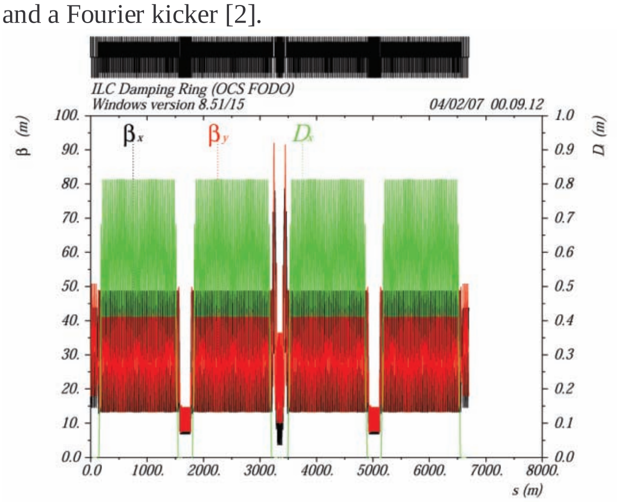

Figure 3: Lattice functions for high alpha case.

There are totally four long straight sections in the ring. The RF cavities and the wigglers have been installed in two of them. The layout of the ring has been designed with 4-fold symmetry. The lattice functions for the whole ring are shown in Figure 3, and the principal lattice parameters are listed in Table 1.

Table 1: The principle lattice parameters.

Circumference [m]	6695.057
Harmonic number	14516
Energy [GeV]	5
Arc cell	FODO
Tune	50.77 / 48.57
Natural chromaticity	-57 / -58
Momentum compaction [10^{-4}]	4
Transverse damping time [ms]	25 / 25
Norm. Natural emittance [mm-mrad]	3.8
RF voltage [MV]	22
Synchrotron tune	0.062
Synchrotron phase [^{o}]	156.8
RF frequency [MHz]	650
RF acceptance [%]	1.466
Natural bunch length [mm]	9.1
Natural energy spread [10^{-3}]	1.28

By tuning the power supply of the quadrupoles in the arc cell, and adjusting the strength of the magnets in the dispersion suppressor and matching sections, we can tune the momentum compaction of the ILC damping ring FODO lattice from 4×10^{-4} to 2×10^{-4}, with the whole lattice design unchanged. For the low momentum compaction case, the RF voltage is 15 MV and the tunes are 60.85/57.9. The lattice functions for the low alpha case are shown in Figure 4.

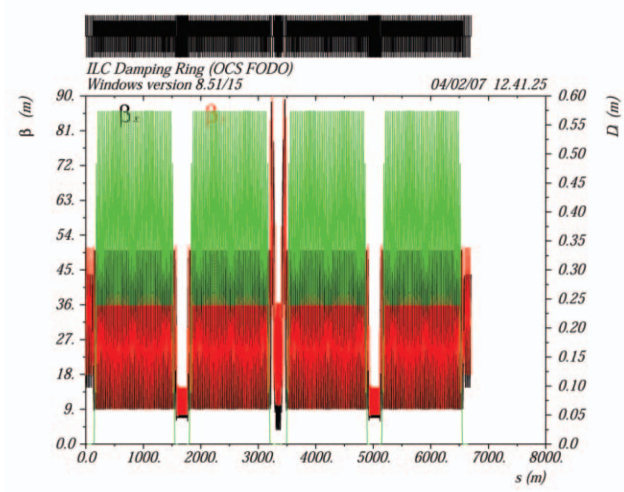

Figure 4: Lattice functions for low alpha case.

In Table 2 a comparison is made between the damping ring baseline design (OCS6) and the alternative design (FODO3). It can be seen clearly that FODO3 uses much smaller number of magnets than OCS6. On the number of access shafts, OCS6 has 4 and FODO3 only has 2.

Table 2: Comparison between damping ring baseline design and alternative design.

	OCS6	FODO3
Circumference [m]	6695	6695
Arc cell	TME	FODO
Phase advance of arc cell	90/90 (108/90)	72/72 (90/72)
Momentum compaction [10^{-4}]	4/2	4/2
Quadrupoles in all	682× 0.3 m	468× 0.2 m
Dipoles in all	120 × 6 m	368 × 2 m
Sextupoles in all	480× 0.25 m	368× 0.25 m
Number of wiggler straights	4	2

SINGLE PARTICLE DYNAMICS

Two family sextupoles in the arc cell are used to correct the first order chromaticity to above zero. The selection of 72/72 degree and 90/90 degree phase advance is to get a second order achromat. It further helps to cancel all driving terms of the third order resonances generated by the sextupoles within each arc section. The straight sections are optimized to give a reasonable horizontal/vertical phase advance (or the phase advance between the last sextupole in one arc section and the first sextupole in the next arc section) which is near π or 2π.

For the 4×10^{-4} momentum compaction case, the variation of tune with momentum spread plus and minus 1% is less than 0.055%. With the high-order magnets errors and the misalignment errors added in, after tracking for 1024 turns, the dynamic apertures of both on-momentum and off-momentum particles are obtained, which are shown in Figure 5 [3].

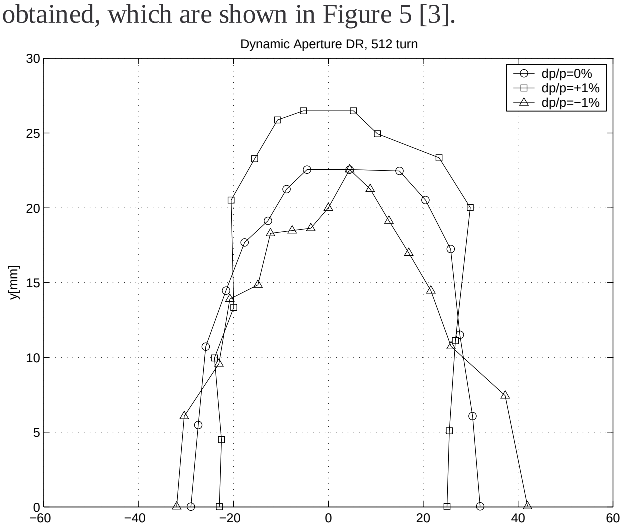

Figure 5: Dynamic aperture (DA) for high alpha case, with all magnets errors and misalignment errors.

It can be calculated from the injected beam's emittance and the beta functions at the injection point of the ring that the horizontal and vertical bunch sizes of the injected beam are approximately 6.6 mm and 4.2 mm, respectively. It can be seen from Figure. 5 that the dynamic aperture is larger than 5 times injected beam sizes for both on momentum particles and off momentum particles.

For the low momentum compaction case, the similar calculation is done and the dynamic aperture with high-order magnets errors is shown in Figure 6, which is still larger than 3 times injected beam sizes.

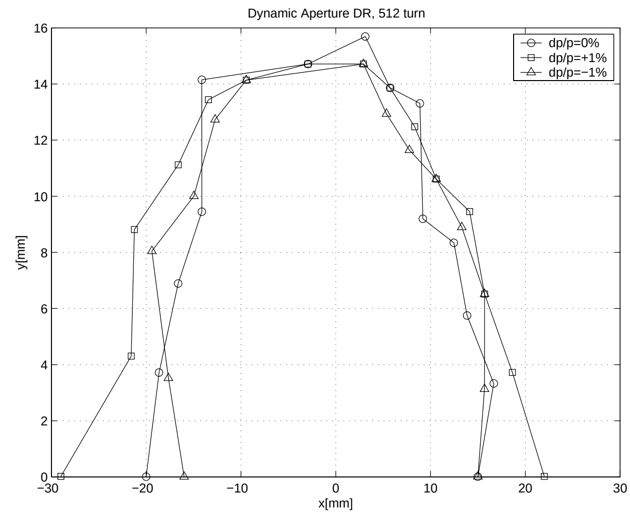

Figure 6: Dynamic aperture for low alpha case, with all magnets errors.

The optimized Frequency Map Analysis (FMA) result for high momentum compaction case is shown in Figure. 7, where 2500 particles distributed in the range of seven times the injected bunch size are tracked for 1024 turns.

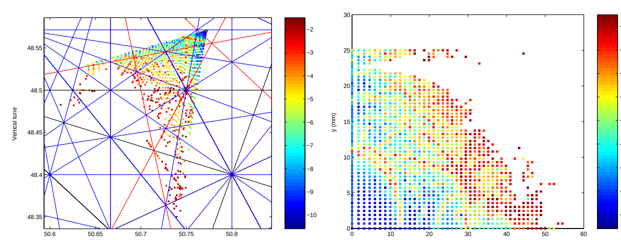

Figure 7: FMA analysis for damping ring DA: (Left) footprint; (Right) Dynamic aperture with FMA.

CONCLUSIONS

The ILC damping ring alternative lattice design is presented. The single particle dynamics are studied. Next step, the lumped injection/extraction kickers, the separated injection/extraction straights, and the Chicane will be studied and designed. Also low emittance tuning associated studies will be carried out on this lattice.

REFERENCES

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[3] A. Terebilo, SLAC-PUB 8732 (2001).

