A LOW EMITTANCE LATTICE FOR THE ILC 3 KM DAMPING RING

S. Guiducci, M. E. Biagini, INFN, Laboratori Nazionali di Frascati, Frascati, Italy

Abstract

A new baseline parameter set has been proposed for the International Linear Collider (ILC) with a reduction by a factor 2 in the number of bunches. This option will allow for a factor of two reduction in the Damping Ring (DR) circumference, with significant cost savings. A low emittance lattice for a 3.2 km long damping ring has been designed, with the same racetrack layout of the present reference 6.4 km long lattice [1] and similar straight sections. The technical work done for the longer ring can be easily applied to the shorter one. The lattice is based on an arc cell design adopted for the SuperB [2] collider and allows some flexibility in tuning emittance and momentum compaction.

INTRODUCTION

A new baseline configuration for the ILC, the SB2009 proposal, has been studied during 2009. SB2009 includes the so-called "Low Power" option, with a factor of two reduction in the number of bunches, that allows for a factor of two reduction in the circumference of the damping rings, leading to a major cost saving. Thus, a new DR design with a 3.2 km circumference has been studied.

From the point of view of beam dynamics and most of the hardware aspects, this change is not expected to cause major performance challenges or technical aggravations, and should provide a firm conceptual basis for more detailed engineering studies during the next Technical Design Phase TDP2.

The proposed new design for the DR will have a racetrack shape [3]. Following the publication of RDR [4] which assumed 6.7 km rings with roughly hexagonal shapes, in discussion at GDE meeting (TILC08), a racetrack ring shape was adopted with 6.4 km circumference and a different arc lattice. The main reason for this choice was tunnel simplification and reduction of the number of shafts and caverns in order to improve operational efficiency and reduce costs. The difference between the new 6.4 km arc lattice and the RDR one has been driven by the decision of reducing the rms bunch length from 9 mm to 6 mm. This reduction has major benefits for the bunch compressors downstream of the damping rings. To achieve a shorter bunch length, for fixed RF voltage and frequency, a lattice with a smaller and flexibly adjustable momentum compaction factor has been chosen [5].

DR PARAMETERS

Figure 1 shows the layout of the 3.2 km damping rings. The electron and positron rings are to be stacked in a common damping ring tunnel located in the central part of the ILC accelerator complex. This construction is fundamentally the same as that put forth in RDR.

Aside from the reduced circumference the fundamental technical design and implementation of the damping rings remain the same as or similar to previous designs. For instance, the bunch separation and the number of particles per bunch remain the same, and the beam current in the ring is the same. Therefore, we expect similar overall performance from the beam optics or beam dynamics viewpoint. Table 1 summarizes the pertinent parameters for the new DR design in comparison with the TILC08 lattice [1].

The technical work done for the long ring can be easily applied to the short one. The lattice still needs some optimization work, but was already used to evaluate some expected beam performances, like the e-cloud instability [6].

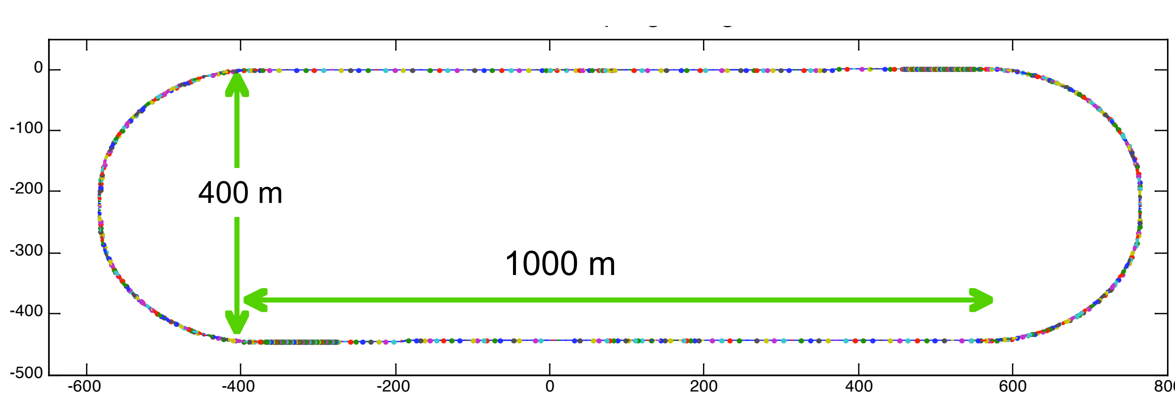

Figure 1: Layout of the 3.2km damping rings.

Table 1: Parameter list for the TILC08 version compared to the SB2009.

	TILC08	SB2009
Energy (GeV)	5	5
Circumference (m)	6476	3238
Number of bunches	2610	1305
N particles/bunch	$2x10^{10}$	$2x10^{10}$
Damping time τ_x (ms)	21	24
Emittance ε_x (nm)	0.48	0.66
Emittance ε_y (pm)	2	2
Momentum compaction	$1.7x10^{-4}$	$1.5x10^{-4}$
Energy loss/turn (MeV)	10.3	4.5
Energy spread	$1.3x10^{-3}$	$1.2x10^{-3}$
Bunch length (mm)	6	6
RF voltage (MV)	21	7.5
RF frequency (MHz)	650	650
B wiggler (T)	1.6	1.6
Total wiggler length (m)	216	78
Number of wigglers	88	32

RINGS LATTICE

The electron and positron ring are arranged one on top of the other with counter-rotating beams. Injection and extraction for each ring are located in the same straight section. RF cavities and wigglers are in the opposite straight section with respect to injection and extraction. The wiggler straight is located downstream of the RF cavities in order to avoid damage by synchrotron radiation.

In the SB2009 lattice, the reduction of the energy radiated per turn and of momentum compaction allows to achieve a shorter bunch length with less than half the number of RF cavities with respect to the RDR. The number of wiggler magnets is 32 instead of 80, less than half, due to the higher field in the arc dipoles. In case a 10 Hz operation is requested for the positron ring (instead of the nominal 5 Hz), the damping time will be halved by increasing the wigglers peak field and decreasing the wigglers period. This would require to double the number of RF cavities.

The lattice in the arcs is based on the SuperB arc cells, two very similar adjacent cells, but with different phase advance (see Figure 2): one is π and the other ~0.75π. By tuning the phase advance in the second cell, the emittance and momentum compaction of the lattice can be tuned.

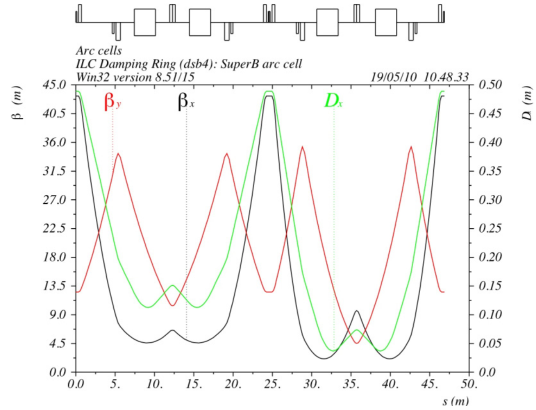

Figure 2: Optical functions of the 3.2km DR arc cells

The optical functions are shown in Figure 3 for the RF and wiggler straight section and in Figure 4 for the injection and extraction straight section. The lattice of both straight sections is made of the same building blocks as used in the longer racetrack lattice. The optical functions for the entire ring are shown in Figure 5.

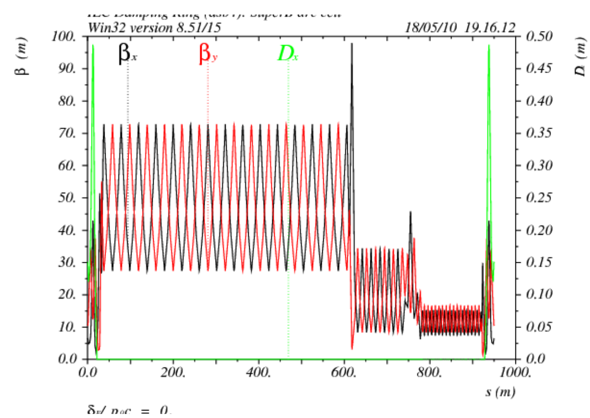

Figure 3: Optical functions of the 3.2 km DR RF and wiggler section

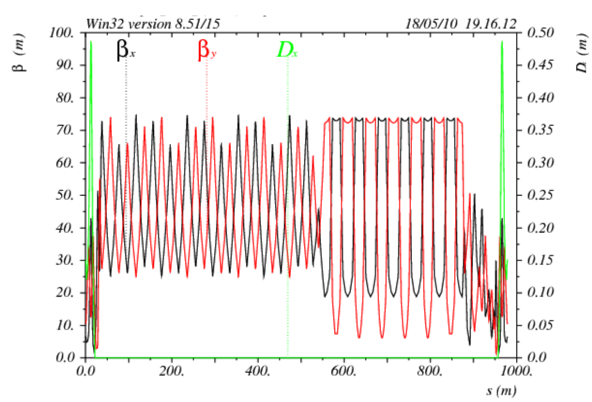

Figure 4: Optical functions of the 3.2 km DR injection and extraction section

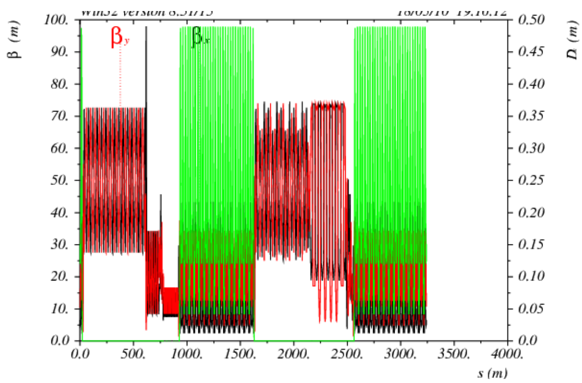

Figure 5: Optical functions of the 3.2 km DR.

DYNAMIC APERTURE

To inject the positron beam with 99% efficiency it is required to accept 3 times the beam sizes with an emittance ε_i = 10^{-6} m rad. The dynamic aperture in number of injected beam sizes for $\Delta p/p$ = 0, +1%, -1% is shown in Figure 6, the maximum injected beam size (3σ) is indicated in black. The corresponding phase space plots are shown in Figure 7. The lattice presented here has a satisfactory aperture in the horizontal phase plane even off energy. This has been achieved by placing the SF sextupoles in pairs with π phase advance distance in between and by adjusting the phase advance in the straights and the total betatron tune of the ring. The dynamic aperture in the vertical plane is just at the limit of the beam size on energy and smaller off energy, it requires more work. We are confident that there is enough flexibility for optimization, in particular retuning the lattice in order to have also the SD sextupoles at π phase advance distance.

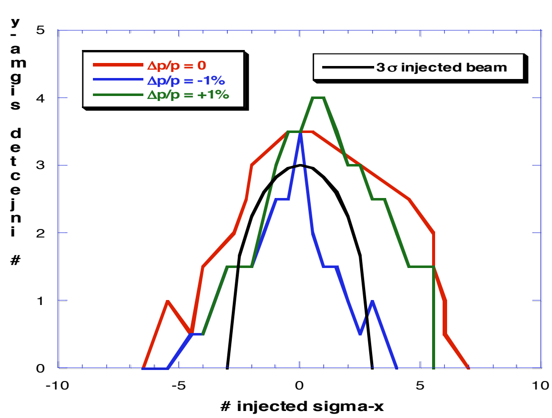

Figure 6: Dynamic aperture in number of injected beam sigmas, for $\Delta p/p$=0 (red), -1% (blue) and +1% (green). In black the maximum (3σ) injected beam size.

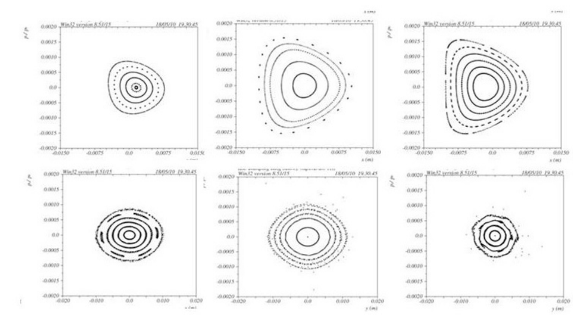

Figure 7: Phase space plots: x (top) and y (bottom) for $\Delta p/p$=0 (centre), 1% (left), -1% (right)

For the dynamic aperture studies the lattice of the straight sections has been simplified with respect to the layout proposed for SB2009. Once we have achieved enough safety margin for the dynamic aperture also in the vertical plane we will fine tune the straights to place the RF and injection/extraction sections in the proper positions.

CONCLUSIONS

A lattice design for a 3.2 Km long DR has been studied. The new lattice, based on the SuperB arc cell design, is still in a preliminary stage of development and requires further optimisation of the dynamic aperture and evaluation of the effects of magnetic errors and alignment errors. However is seems to satisfy all the requirements in terms of emittance, momentum compaction and ring flexibility.

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