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THE NEXT LINEAR COLLIDER DAMPING RING COMPLEX*

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Abstract

We report progress on the design of the Next Linear Collider (NLC) Damping Rings complex (DRC) [1]. The purpose of the DRC is to provide 120 Hz, low emittance electron and positron bunch trains to the NLC linacs [2]. It consists of two 1.98 GeV main damping rings, one positron pre-damping ring, two pairs of bunch length and energy compressor systems and interconnecting transport lines. The 2 main damping rings store up to 0.8 amp in 3 trains of 95 bunches each and have normalized extracted beam emittances $\gamma\varepsilon_x$ = 3 μm-rad and $\gamma\varepsilon_y$ = 0.03 μm-rad. The preliminary optical design, performance specifications and tolerances are given in [1]. Key subsystems include 1) the 714 MHz RF system [3], 2) the 60 ns risetime injection / extraction pulsed kicker magnets [4], 3) the 44 m wiggler magnet system, 4) the arc and wiggler vacuum system, 5) the radiation management system, 6) the beam diagnostic instrumentation, 7) special systems used for downstream machine protection and 8) feedback-based stabilization systems. Experience at the SLAC Linear Collider has shown that the NLC damping rings will have a pivotal role in the operation of the high power linacs. The ring dynamics and instabilities will in part determine the design choices made for the NLC machine protection system. This paper includes a summary overview of the main ring design and key subsystem components.

Table 1: Main Damping Ring and Pre-Damping Ring parameters.

	Main Rings	Pre- Ring
Energy GeV	1.98	1.98
Circ. meter	297	214
Rotation frequency MHz ($1/T_0$)	1.01	1.401
RF (MHz)	714	714
h	708	510
τ_b (bunch spacing)	2.80 ns	2.80 ns
Fill pattern (# trains N_T, /# bunches)	N_T=3/ 95 3 gaps 68 ns	N_T =2/ 95 2 gaps 100 ns
$\tau_{x,y}$ (ms)	< 5.21	< 5.21
N_{max} /bunch	1.6×10^{10}	1.9×10^{10}
I_{max} (Amp)	0.75	0.80
Normalized extracted emittance $\gamma\varepsilon_x$ / $\gamma\varepsilon_y$	< 3/.03 μm-rad	<100 μm-rad
ε_x / ε_y	<800/8 pm-rad	<25 nm-rad
Gap voltage V_g (MV)	1.5 (3 cells)	2 (4 cells)
Loss/turn U_0	750 KeV	400 KeV
Momentum compaction α_p	6.6×10^{-4}	0.0051
Injected emittance $\gamma\varepsilon_{x0,y0}$	150 μm-rad	> 0.06 m-rad (Acceptance)
Bunch length σ_z	4.0 mm	8.4 mm
Energy acceptance	+/- 1.9%	+/- 1.3%

1 INTRODUCTION

The DRC provides damped e^+/e^- beams to the bunch length compressors at either end of the NLC. A pre-damping ring is required for e^+ because of the large source emittance. Except for the pre-damping ring and its associated transport lines, the e^+/e^- systems are identical. Figure 1 shows the layout of the e^+ rings.

In this paper we first review the optics design of the main damping ring and then describe progress on some critical subsystems. The pre-damping ring will be the topic of a future report.

2 DESIGN

The main damping ring design was substantially redone in order to accommodate a 2x larger inter-bunch spacing (τ_b). The equilibrium emittance (ε_{ye}) in the updated design was allowed to be relatively large, 0.02 μm-rad, so that component placement tolerances are not extreme. The optimum number of vertical damping times (N_τ) was then set by the emittance at injection such that ε_y is $1.5\varepsilon_{ye}$; resulting in N_τ=4.8. The vertical damping time (τ_y) is then

$$\tau_y \le \frac{N_T}{N_\tau f} = \frac{3}{4.8\cdot(120Hz)} \approx 5.2m\sec \ge \frac{(2.9\times10^{12}kG)T_0}{B_0\gamma^2}$$

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determined and the arc bend field ($B0$) is given above. A wiggler is needed to keep $B0$ reasonable at 1.98 GeV. The wiggler length (L_W) required is given by:

$$L_w \geq 6C \frac{(B\rho)^2}{r_e c \tau_y \gamma^3 B_w^2} \cdot \frac{F_w}{1+F_w} \geq 33m(B_w = 2.15T)$$

where B_W is the peak field of the wiggler. We have chosen a racetrack shape with the wiggler on one side and injection/extraction, RF, abort and feedback systems on the other.

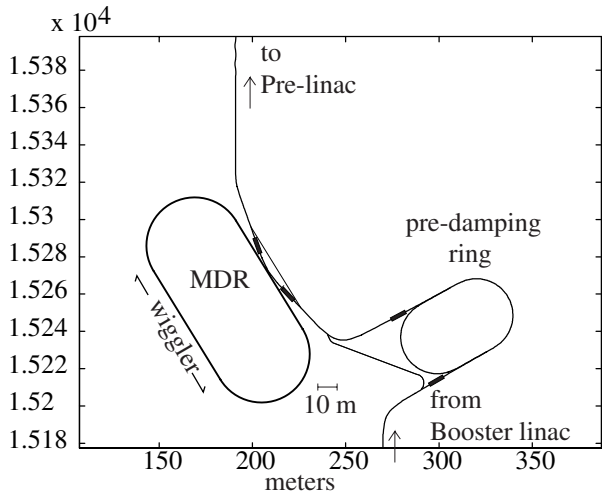

Figure 1: NLC e^+ damping ring complex shown with its associated transport lines and the first bunch length compressor (BC) stage (the BC wiggler is barely visible at the top of the figure). Two short bypass lines, to be used during construction and for possible future e^-/e^- operation can also be seen. The scale is in meters, referenced to the center of the NLC complex.

Table 2: Lattice parameters for the main damping ring.

ν_x / ν_y	23.85 / 11.23
#TME cells / length per cell	30 / 6.01 m
Phase adv. per TME ½ cell (x/y)	108 / 45 degrees
Straight length	58 m
Wiggler (length L_W / period λ / peak field B_W)	44 m / 0.27 m / 2.15 T
$U_{wiggler} / U_{arc} = F_W$ (ratio of wiggler loss/arc loss)	2.3

Detuned theoretical minimum emittance (TME) optics [5] are used in the arcs. The detuning factor (r) is set by 3 considerations: 1) to keep α_p as large as possible in order to stabilize the ring extraction energy and keep the transient longitudinal bunch length instability threshold as high as possible[6], 2) to reduce typical sextupole strength and 3) to minimize the number of cells. We have chosen r= 1.6. The ratio of damping done by the wiggler to that done in the arc (F_W) was also chosen to keep α_p large.

The ring extraction energy stability tolerance, $\Delta\delta$, is about 10% of the natural energy spread, $\sigma\delta \sim 10^{-3}$. The stability requirement for the ring size (C), is:

$$\Delta C \leq \alpha_p \Delta_\delta C \approx 20\mu m \left(\alpha_p = 6.6\times10^{-4}\right)$$

Relatively slow changes [7], (< 1 Hz), in C can be compensated by a magnetic chicane[8]. Faster changes, coming perhaps from ground vibration, may be a concern. RF frequency correction, used in storage rings to compensate for ring size drifts, is cumbersome in the damping ring because the extracted train is subsequently injected into a linac whose frequency cannot be varied.

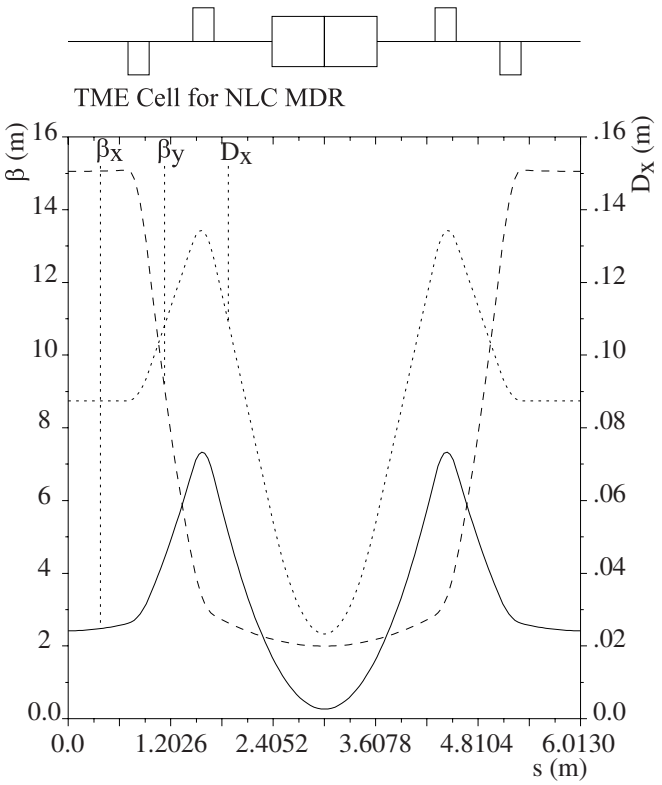

Figure 2: Optical functions of the 6 m DFBFD detuned TME arc cell. The top of the figure shows the QD, QF and bend magnets; the 4 sextupoles are not shown.

3 TECHNOLOGY

In many ways, the damping ring is similar to a 3rd generation light source with its high current, small coupling, low vacuum pressure (<1nTorr) and large synchrotron radiation power loading. In addition, the damping ring complex includes several challenges associated with fast damping, high throughput injection from a powerful injector, and clean extraction.

High current transient operation, where the rings can be filled and emptied in a few injector linac pulses, is peculiar to damping rings. The RF is the system most affected by the transients. We are developing a heavily higher-order-mode damped cavity design, adapted from the PEP-II work, with a high level of control, feedback

and feedforward applied. The flexible low-level controls and feedback loops to control beam phase and energy under a variety of beam conditions are described in [9]. Since the damping ring uses on-axis injection/extraction, a large inter-train gap is left for the kicker rise and fall time. The gap transient [10] may be controlled with the use of feedforward through the klystron.

Our kicker design is modeled after the low beam impedance stripline kicker developed at DELTA [11]. Because of the difficulty of achieving proper performance with the SLC damping ring injection and extraction kickers[12],[13], development work on this system is important even though the requirements for the NLC rings are substantially reduced. In the prototype, a pair of shorted striplines is differentially driven from a 330 amp low voltage solid state pulser [14].

The 44 m wiggler section is a concern because of its high field strength and large size. Several technologies are under consideration for the wiggler; 1) electromagnet, 2) NdFe:B permanent magnet, and 3) superconducting magnet. Injected beam radiation damage effects are a serious concern, especially for 2) and 3). Some components close to the beam pipe in the SLC damping rings were exposed to 10^{14} rad [15] over a 5 year period. This level could result in partial demagnetization of permanent magnets and may be a heat load problem for a superconducting magnet. Since the NLC injector linac is 6 times more powerful than the SLC injector, the potential exists for higher radiation exposure rates. A collimation system will be needed for protection of the wiggler.

The vacuum chamber through the wiggler must be capable of dissipating about 60 W/cm. While this is ~3x less than a similar system in the PEPII LER [16], the specified pressure ceiling is 10x lower and work is underway to develop a symmetric antechamber design. Even though the typical trajectory distortion caused by the wiggler field is small, about 1 mm, the wiggler is so long that 90% of the radiation is dissipated within the straight section itself.

Since the primary purpose of the damping rings is to produce very low emittance beams, there are several sets of transverse and longitudinal beam size monitors. Typical transverse beam sizes are σ_x=100 x σ_y=10 μm, sizes too small for conventional wire scanner or video imaging techniques at the nominal full train intensity of 1.4×10^{12} e^+/e^- per pulse. Downstream of the ring, in BC1, a sequence of laser-based profile monitors [17] is used to measure emittance and energy spread.

Several special purpose subsystems in the damping ring will be used to integrate its operation with the operation of the collider as a whole. The most important of these is the machine protection system [18]. An emittance spoiler will, in the duration of a few pulses, increase the emittance to safe levels for injection of a single pulse into the main linac and the pulsed abort magnet that will be used to quickly dump the beam in the event of a downstream fault.

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