THE PROPOSED CONVERSION OF CESR TO AN ILC DAMPING RING TEST FACILITY*

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Abstract

In 2008 the Cornell Electron Storage Ring (CESR) will end nearly three decades of providing electron-positron collisions for the CLEO experiment. At that time it will be possible to reconfigure CESR as a damping ring test facility, CesrTF, for the International Linear Collider (ILC) project. With its 12 damping wigglers, CesrTF will offer horizontal emittances in the few nanometer range and, ideally, vertical emittances approaching those specified for the ILC damping rings. An important feature of the CesrTF concept is the ability to operate with positrons or electrons. Positron operation will allow detailed testing of electron cloud issues critical for the operation of the ILC positron damping rings. Other key features include operation with wigglers that meet or exceed all ILC damping ring requirements, the ability to operate from 1.5 to 5.5 GeV beam energies, and the provision of a large insertion region for testing damping ring hardware. We discuss in detail the CesrTF machine parameters, critical conversion issues, and experimental reach for damping ring studies.

CESR TEST FACILITY OVERVIEW

At the conclusion of the CESR-c/CLEO-c charm physics program, CESR can be made available as a dedicated test facility, CesrTF, for ILC damping ring studies. As the world's only operating wiggler-dominated storage ring, CESR offers a unique facility with which to investigate beam physics and instrumentation critical to the design and operation of the ILC damping rings. The CESR-c damping wigglers are the technology choice for the ILC baseline design. A core component of the CesrTF research program will be to study the electron cloud effect (ECE) in these devices and techniques to suppress it. The changes required to make CESR available as a test facility are modest so that research results will be available in a timely fashion for use by the ILC program.

An experimental program to understand the relevant ECE physics requires a positron beam, very small vertical emittance, and high field damping wigglers. Ideally, the zero current limit of the vertical emittance should be comparable to the specifications of the ILC damping rings to provide sensitivity to the emittance diluting effects of the ECE. We intend to use CesrTF to determine how the development of the electron cloud depends on beam parameters, local magnetic fields, and vacuum chamber design. ECE instability thresholds will also be measured. Flexibility of the bunch structure of the beam is essential in exploring the dependence of the ECE on bunch spacing and train length. Such flexibility can be provided by a straightforward upgrade to the CESR feedback system which will allow operation with bunch spacings as short as 4 ns [1]. Simulations indicate that the equilibrium electron cloud density will be highest in the ILC damping ring wigglers [2] and we intend to create an instrumented wiggler section to study this in detail. A comparison of measurement with simulation will help validate the models that are the basis of the ILC damping ring design. Additionally, tests of ECE suppression techniques in the wigglers will be crucial for finalizing the ILC design.

A range of damping ring phenomena and technologies can be investigated in a dedicated facility. The CESR operations group has developed sophisticated tools for correcting orbit, focusing, coupling, and dispersion errors using beam based measurements. We intend to apply existing techniques to the task of achieving the few picometer vertical emittance specified for the ILC design, so that we can understand the limitations and to implement new algorithms as required. Achieving ultra-low vertical emittance will necessarily be coupled with tests of new instrumentation designed to measure the very small beam size. The flexibility to store closely spaced bunches will permit tests of fast extraction kickers and pulsers. The CESR injector can deliver electron as well as positron beams, allowing for the possibility of measuring effects peculiar to electrons (as well as positrons), like the fast ion instability, and to distinguish species dependent effects.

TEST FACILITY DESIGN

In order to obtain the smallest possible beam emittance, the CESR-c wigglers need to be located in regions with zero dispersion. CESR has two 18 m long interaction regions (IR) that meet this criteria. 6 of the 12 wigglers, which are presently located in the arcs of the machine, will be moved to the North IR. This move will require adding cryogenics support to that region. Our simulations indicate that the other two triplets of wigglers can remain in place by creating local zero dispersion regions. This will leave the South IR available for insertion devices such as specialized beam instrumentation, prototype damping ring hardware, etc. There is also space available adjacent to the South IR which could accommodate an extraction line if that becomes desirable.

Figure 1 shows the optics functions for our baseline lattice design. Key machine parameters for this configuration are given in Table 1. The integer horizontal tune in this de-

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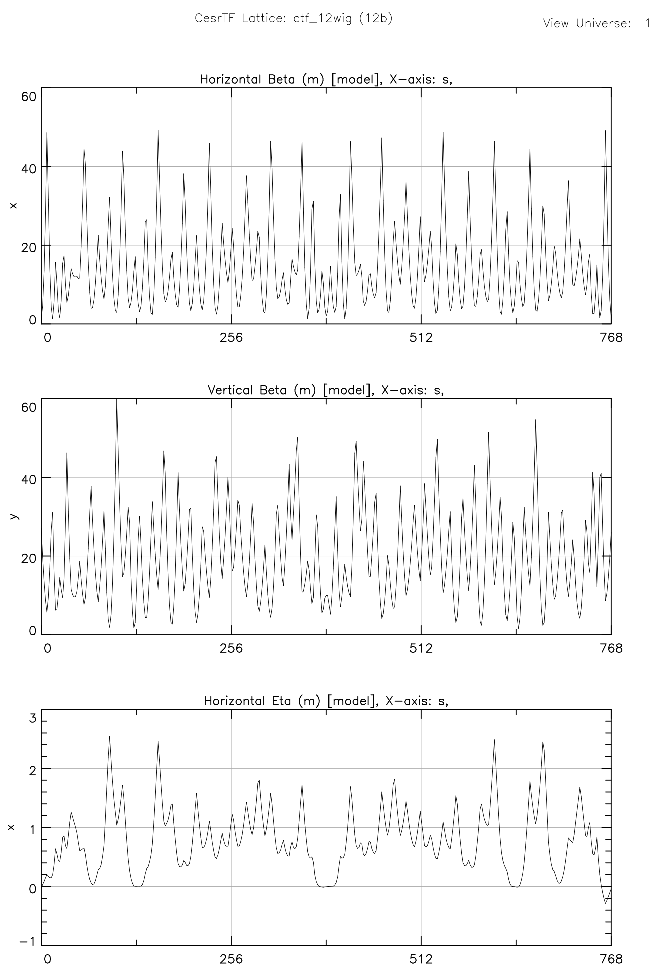

Figure 1: CesrTF Lattice Parameters for 2.0 GeV Operation

Table 1: CesrTF Parameters. Note that RF accelerating voltage is based on installing 2 spare CESR SRF cavities in the South IR for short bunch length operation.

Parameter	Value
No. Wigglers	12
Wiggler Field	2.1 T
Beam Energy	2.0 GeV
Energy Spread ($\Delta E/E$)	8.6×10^{-4}
Horizontal Emittance	2.25 nm
Transverse Damping Time	47 ms
Q_x	14.59
Q_y	9.63
Q_z	0.098
Total RF Voltage	15 MV
Bunch Length	6.8 mm
Momentum Compaction	6.4×10^{-3}

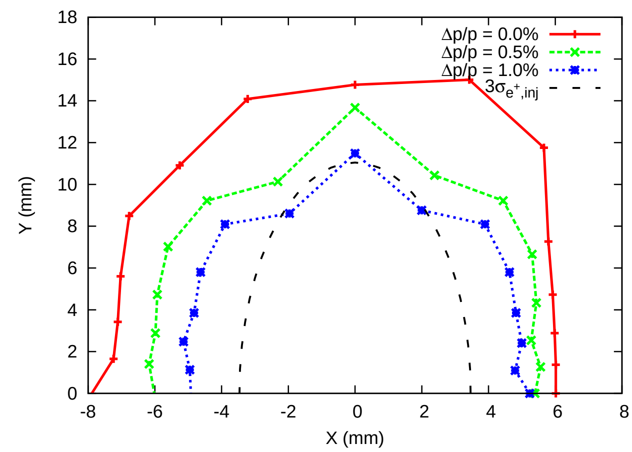

Figure 2: CesrTF dynamic aperture for 0.5% and 1% energy offsets. The dashed curve corresponds to 3σ of the the rms size of the injected beam.

sign has been chosen to minimize the emittance. Our goal is a vertical emittances in the 5-10 pm range for our beam dynamics studies. Touschek estimates for the 5 pm case and 2×10^{10} particles per bunch (the ILC design specification) yield a lifetime of approximately 7 minutes.

The dynamic aperture of these optics has been evaluated for fractional energy offsets of 0.5% and 1% and is shown in Figure 2. The tracking code employs the same wiggler map as is used for CESR-c calculations [3]. Particles are considered lost when their amplitude significantly exceeds the real physical aperture. The horizontal emittance of the injected beam is assumed to be 1000 nm. The beam is also taken to be fully coupled so that the vertical emittance is half the horizontal (500 nm). These results indicate an acceptable dynamic aperture.

LOW EMITTANCE OPERATION

Our ability to operate CesrTF in the ultra-low emittance mode proposed above is strongly dependent on our ability to correct for magnet misalignments and on the impact of beam dynamics effects, in particular intrabeam scattering (IBS). In this section, we describe our initial evaluations of these issues.

Magnet misalignments in CESR create vertical dispersion and couple horizontal and vertical emittance. In order to achieve the target vertical emittance, the sensitivity to misalignments has been characterized and algorithms for correcting misalignments are being evaluated. Table 2 shows the nominal alignments we expect to achieve with existing survey techniques [4]. The dominant sensitivity is to vertical offsets of the CESR quadrupoles.

Simulations have been performed incorporating the ran-

Table 2: Nominal magnet misalignments in CESR

Element	**Misalignment**
quad, bend, and wiggler offset	150 μm
sextupole offset	300 μm
quad, bend, wiggler, and sextupole roll	100 μrad

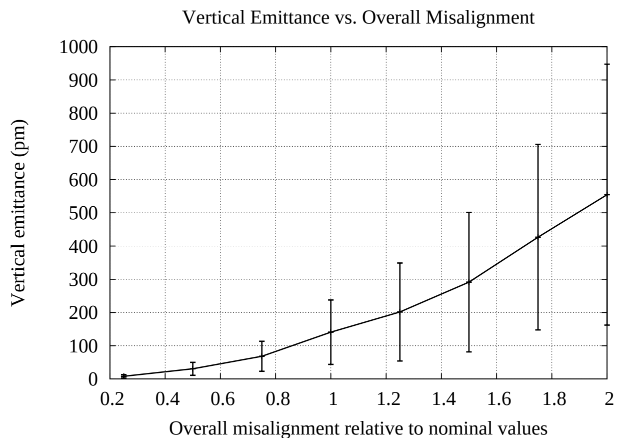

Figure 3: Impact of magnet misalignment on uncorrected vertical emittance

dom misalignment of elements using multiple seeds. Figure 3 shows that, at the nominal level of misalignment, the uncorrected vertical emittance in CesrTF would be approximately 140 pm. If the overall alignment tolerances could be improved by a factor of four, the vertical emittance would drop to ~ 8 pm without correction. In order to compensate for the effects of magnet misalignment, steering magnets and skew quadrupoles are used to correct the measured orbit distortion and dispersion. This technique has been evaluated using simulations which take into account BPM resolution. When all magnet misalignments are set to the nominal values, as given in Table 2, the corrected vertical emittances that are obtained are shown in Table 3. These values are consistent with our target values for the vertical emittance.

Table 3: Corrected Vertical Emittances for Nominal Magnet Misalignments

Correction Type	**Average Value**	**95% Limit**
Orbit Only	10.2 pm	21.4 pm
Orbit+Dispersion	3.9 pm	8.2 pm

We have also carried out a preliminary evaluation of IBS effects [5]. For our baseline 2.0 GeV lattice, with $\epsilon_x = 2.25$ nm, we find that the horizontal emittance grows by a factor of 2.2 as we move from the zero current limit to a bunch with 1×10^{10} particles. For an ILC bunch with 2×10^{10} particles, the horizontal emittance is 2.9 times larger than the zero current value. In the limit that the vertical emittance is dominantly due to coupling, these same growth factors will apply. Since the IBS growth rates scale as γ^{-4}, the emittance blowup can be significantly ameliorated by lengthening the bunch, or, at the expense of a slightly larger zero current emittance, moving to higher energy. We have explored a 2.5 GeV lattice with 9 mm bunch length which ranges between $\epsilon_x = 2.85$ nm at zero current and $\epsilon_x \sim 4.5$ nm at 2×10^{10} particles per bunch. This flexibility to control the operating conditions in CESR gives us strong confidence that a viable experimental plan for low emittance beam dynamics tests can be successfully implemented.

CONCLUSION

If conversion to CesrTF commences immediately at the end of scheduled CESR-c/CLEO-c operations, it is expected that machine commissioning would start by late 2008. CesrTF would then be available for use by interested collaborators in early 2009. We envision roughly 110 days of operation per year divided into two separate runs with synchrotron light running (at 5.3 GeV) for the Cornell High Energy Synchrotron Source (CHESS) in between. The CHESS runs will provide regular high energy scrubbing of the CESR vacuum chambers. Significant downtime during each transition would be provided to allow for machine maintenance, as well as installation of prototype devices and hardware required for the damping ring research program. We intend to make the facility available for a minimum of 3 years of operation as the ILC moves towards the start of construction.

Simulations indicate that CesrTF can be operated in a regime that is useful for a range of damping ring studies. In particular, CesrTF will have the ability to study physics issues associated with the damping wigglers and validate the final design of the ILC wigglers and vacuum chamber. The machine will be able to directly explore the impact of the electron cloud on the emittance. Due to the modest scope of the conversion, CesrTF offers an efficient route towards exploring key areas of ILC damping ring physics and technology on a timescale consistent with the start of ILC construction.

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