DESIGN CONSIDERATIONS AND MODELING RESULTS FOR ILC DAMPING RING WIGGLERS BASED ON THE CESR-C SUPERCONDUCTING WIGGLER

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Abstract

The International Linear Collider (ILC) damping rings will require construction of wiggler magnets of high field quality on a large scale. We consider various designs derived from the wigglers presently in operation at the Cornell Electron Storage Ring (CESR). Design optimization has been performed based on detailed tracking calculations of dynamic aperture and tune footprint in a full model of the damping ring. Results on finite-element modelling, transfer functions, and implications for the final engineering design will be discussed.

INTRODUCTION

The baseline technology choice for the ILC damping ring wigglers is a superferric wiggler [1] based on the design developed for the CESR-c program [2, 3]. The baseline design as described in the ILC Reference Design Report [4] (RDR) is a 14 pole wiggler with 40 cm period and a peak B field of 1.67 T. After the baseline decision, work was carried out to prepare an optimized physics design for the damping wiggler [5, 6]. The resulting wiggler concept was for a unit with larger pole gap, shorter period, and a higher peak field. Table 1 compares the parameters of the CESR-c wiggler, the ILC RDR wiggler, and the recently proposed optimized ILC wiggler.

WIGGLER DESIGN OPTIMIZATION

The conversion of the CESR storage ring in 2001 from investigations of bottom quark bound states to charm quark bound states necessitated the design, construction and implementation of superconducting wiggler magnets to restore the damping lost by lowering the beam energy from 5 to 2 GeV. [7, 9] In addition, an analytic model of the wiggler field was developed to allow fast tracking in models used for designing the damping-dominated lattice. [8] This background served as a starting point for the development of various options for the ILC damping ring wiggler described above. A full 3D model using the OPERA magnetostatics package from Vector Fields [10] has now been developed for the optimized version of the ILC superferric wiggler, as shown in Fig. 1.

Salient characteristics of this new design include twelve poles of 16-cm length and 23.8 cm width, a vertical gap of 8.64 cm, 660-turn main coils carrying 93 kA to provide a peak field of 1.95 T (see Fig. 2).

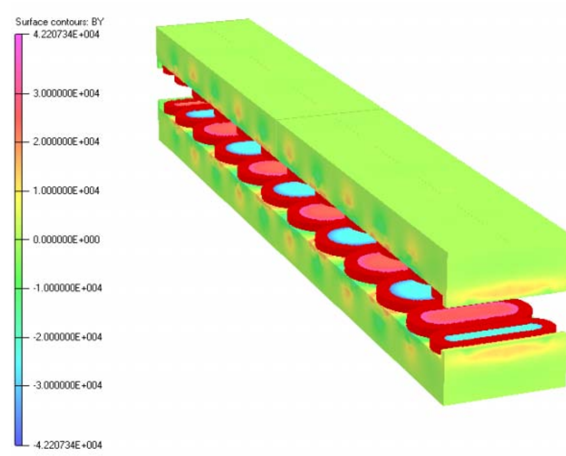

Figure 1: 12-pole optimized damping ring wiggler. The color scale on the surface of the model shows the magnitude of the vertical magnetic field component.

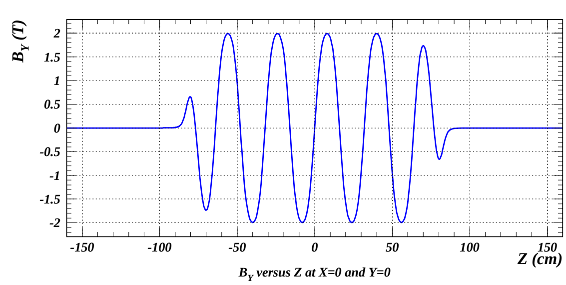

Figure 2: On-axis vertical field component.

The 3/4- and 1/2-pole-length tapering in the end poles has been maintained as in the CESR design. The stringent tolerance on horizontal field rolloff originally motivated by the CESR pretzel orbits was relaxed, allowing the omission of field-shaping pole face cutouts. The resulting horizontal rolloff of the vertical field component in a central pole is shown in Fig. 3. The width of the end-pole main coils has been tuned to 1.54 cm comprising 398 turns, the same density as in the main pole coils, largely cancelling the second field integral and reducing the residual horizontal orbit displacement for 5 GeV electrons incident on axis to less than 20 μm, as shown in Figs. 4 and 5. Trim coils of 1 cm width comprising 710 turns, which is the density of the CESR trim coils, are included in the design, the trim current be-

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Table 1: Superferric Wiggler Comparison

Parameter	Unit	CESR-c	ILC Baseline	ILC Optimized
Peak Field	T	2.10	1.67	1.95
No. Poles		8	14	12
Length	m	1.3	2.5	1.68
Period	m	0.40	0.40	0.32
Pole Width	cm	23.8	23.8	23.8
Pole Gap	cm	7.6	7.6	8.6
dB/B (x=10mm)	%	0.0077	0.0077	0.06
Coil Current	A	141	112	141
Beam Energy	GeV	1.5–2.5	5	5

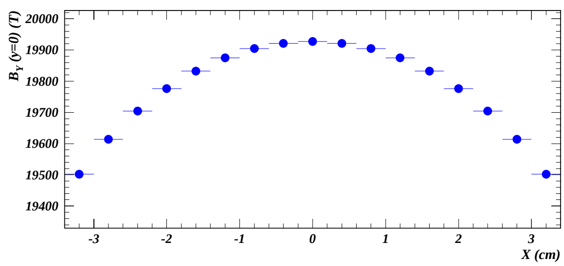

Figure 3: Dependence of the vertical field component on the transverse coordinate in the horizontal midplane for a central pole.

ing set to zero for the field results described here. As in the CESR-c design, energizing these coils in series with a single power supply results in correcting the second integral of the field, and therefore the orbit offset, rather than the angle kick. This horizontal orbit oscillation and the alternating

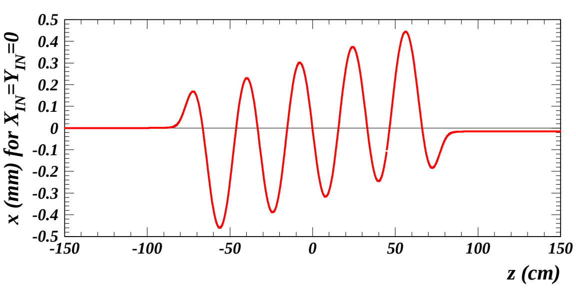

Figure 4: Trajectory in the horizontal plane for 5 GeV electrons of perpendicular incidence on the symmetry axis of the wiggler.

longitudinal field field component result in a vertically focusing effect. Figure 6 shows the corresponding transfer function for 5 GeV electrons of perpendicular incidence in the vertical symmetry plane.

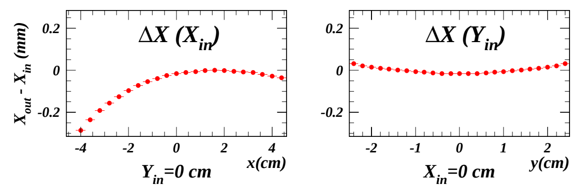

Figure 5: Horizontal orbit displacement at the exit of the optimized wiggler for 5 GeV electrons of perpendicular incidence on the horizontal and vertical planes of symmetry as a function of the horizontal and vertical entrance positions.

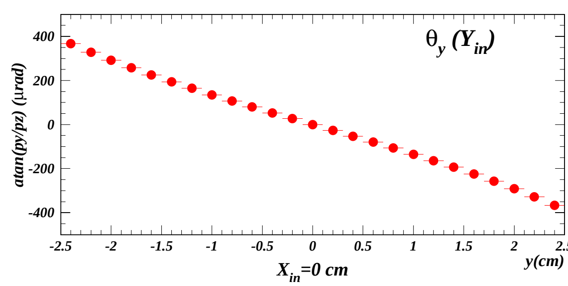

Figure 6: Vertical orbit angular kick at the exit of the optimized wiggler for 5 GeV electrons of perpendicular incidence in the vertical plane of symmetry as a function of the vertical entrance position.

ENGINEERING AND COST CONSIDERATIONS

The key engineering issues associated with the optimized ILC design are the increase in pole gap, the smaller number of poles, and the shorter overall length of the unit. The primary reason for the increase in pole gap is to provide space for a separate warm vacuum chamber to fit through the magnet bore. In the case of the CESR-c design, the vacuum chamber was integral to the cryostat. For the ILC, a separate vacuum chamber will allow the synchrotron radiation load on the chamber to be handled more readily and will also simplify assembly. The smaller number of poles will simplify the wiggler construction and decrease coil winding costs. The shorter overall length for the wiggler will simplify the vacuum chamber interface, decrease construction costs due to the smaller cryostat, and will allow for a simplified and more robust process for assembling the magnet yokes.

A number of cryogenic changes are envisioned for the optimized wiggler design. Because liquid nitrogen (LN_2) will not be allowed in the ILC tunnels, intermediate temperature shields will have to be cooled with cold He gas. Also, it is proposed to switch to indirect cooling for the cold mass instead of relying on liquid He bath cooling as is the case in the CESR-c design. These changes represent significant simplifications to the cryostat and cryogenic stack designs. Without these changes, the manpower required to construct the inner cryostat for bath cooling and the cryogenic stack represent over 40% of the total manpower budget for wiggler construction. When combined with the cost savings from building a smaller wiggler unit, it is quite likely that savings in excess of 25% of the present wiggler cost estimate are possible.

CONCLUSIONS

Design and modeling work for the optimized ILC wiggler design are ongoing. The next major milestone in the modeling effort will be the generation of an analytic model as was done for the CESR-c wiggler [8]. The analytic model will allow fast symplectic tracking through the ILC wigglers for beam dynamics studies.

A number of possible modifications have been identified which are excellent candidates for incorporation into the final ILC damping ring wiggler design. Several of these modifications have potentially large and beneficial cost impact and will be actively pursued during the engineering design phase.

Finally, information about the various superferric wiggler designs, including detailed field maps and documentation, is available online at:
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/WigglerInfo

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