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Wiggler Magnet Optimization for Linear Collider Damping Ring

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Abstract

Optimization results of a permanent magnet wiggler by 3D field calculation are shown. The developed model of optimization provides significant decreasing of field nonlinearity in a wiggler gap. Proposed wiggler optimization is executed on the example of a TESLA damping ring (DR) and can be used at designing of ILC DR.

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1 Introduction

The magnetic design of the damping wiggler, as proposed in the TESLA TDR [1], has not been optimized. The transverse good-field region of wiggler magnet is not wide enough and leads to a reduction of dynamic aperture [2], due to the resulting magnetic field nonlinearity connected with the finite wiggler pole width. One of the ways to reduce the wiggler field nonlinearity is to increase the pole width.

For this study, the pole width has been increased from 40 mm to 60 mm while the overall design has not been changed [2]. The axial and top magnets have been scaled with the increased pole size whereas the side magnets have not been changed. This provides an increase in magnetic field homogeneity region, but at the expense of cost and weight.

2 Wiggler magnetic design optimization

The main parameters of a wiggler magnet for a pole-width of 60 mm are the following.

The wiggler consist of a permanent magnet hybrid structure with a period length $\lambda = 400$ mm and a fixed gap of 25 mm. The cross section is 220x385 mm^2. The poles have dimensions of 100x60x100mm^3 (LxWxH) with a symmetric chamfer of 5 mm corresponding to the pole overhang in the gap region, and are made of low carbon steel. NdFeB with a remanence of Mr ~ 1.15 T is used for the axial, side and top magnets with dimensions of 100x60x95 mm^3, 100x50x95 mm^3, 100x60x50 mm^3, respectively.

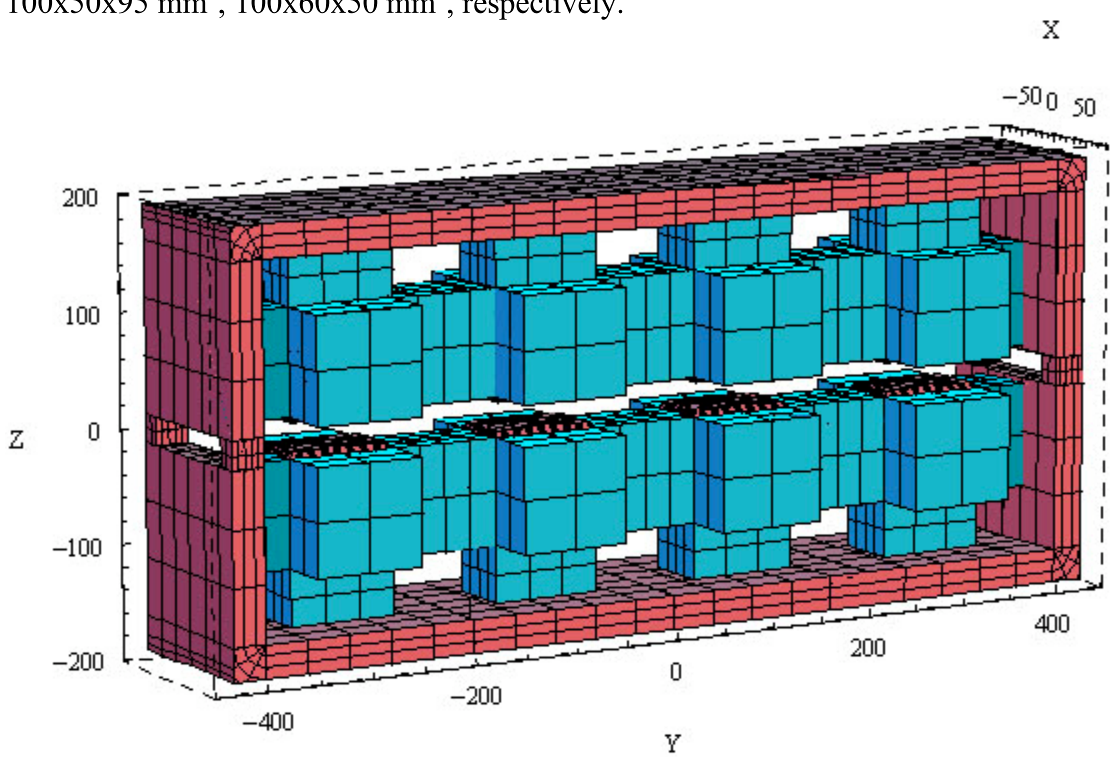

Figure1: Wiggler magnet for 2 periods displayed with dismantled iron yoke sides.

An iron plate with a thickness of 30 mm encloses the whole wiggler and acts as magnetic yoke. There is an opening in the yoke face for the vacuum pipe of 25x120 mm^2. Two periods of the wiggler magnet are shown in Figure1 for illustration. The overall total length of wiggler segment is 5.26 m and contains 12 full periods plus 2 half periods for the end poles [2].

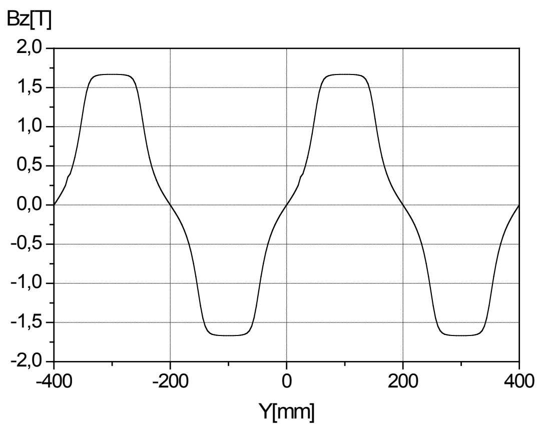

Figure 2: Vertical field along the wiggler axis.

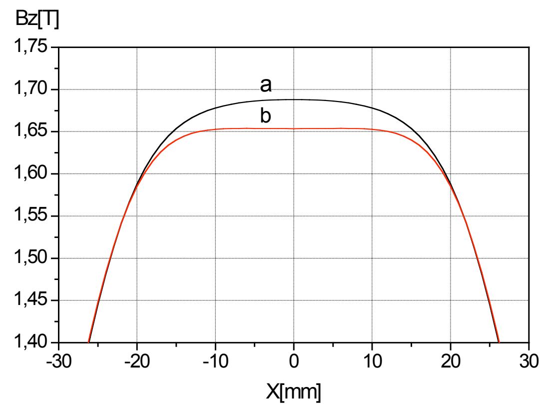

Figure 3: Transversal field distribution Bz(x) in the orbit plane Z=0 at the pole center: a–without optimization, b–with optimization

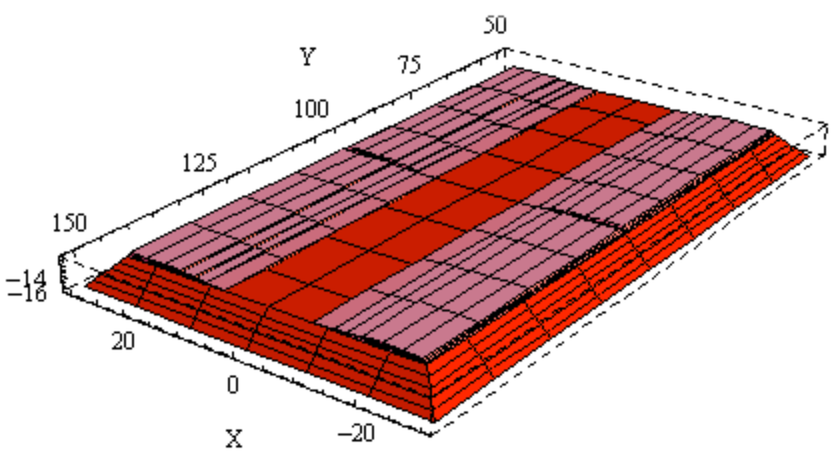

Figure 4: A view of wiggler pole profile optimized with four slots.

Wiggler design optimization has been achieved by means of slots, which are made symmetrically about the central axis along the length of a pole as shown in Fig.4. Various configurations of a pole surface have been considered. Optimization has been achieved by using four slots. The slots have various depths and widths. Total depth of the slots is 0.45 mm. Thus in the center of a pole the size of a gap is 25.9 mm. The center field Bo is reduced by ~2%. Calculations are performed by code 3D Radia [3].

Table 1: Results of comparison for a pole width of 60 mm

	Without optimization	With optimization
Peak field B_0	1.68	1.65
Homogeneity $\Delta B/B_0$ $X = \pm 1$ mm $X = \pm 5$ mm $X = \pm 10$ mm	 $3.6\ 10^{-5}$ $1.1\ 10^{-3}$ $5.9\ 10^{-3}$	 $-1.0\ 10^{-5}$ $-1.1\ 10^{-4}$ $5.5\ 10^{-4}$
Reduction B_0 (%)	-	2.0
Total slots depth (mm)	-	0.45

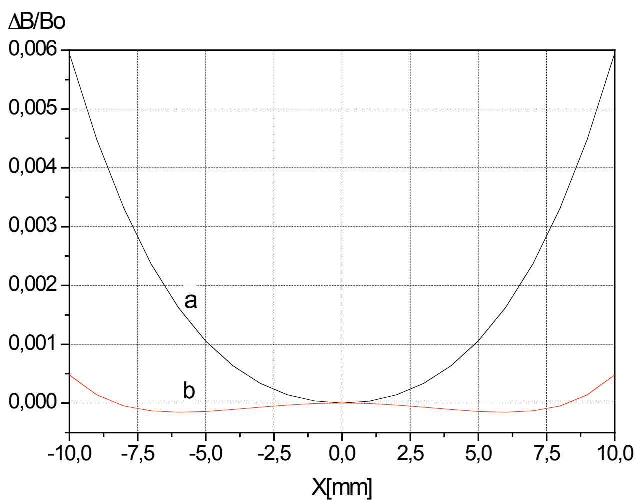

Figure 5: Relative change of magnetic field homogeneity in transverse direction at the pole center: a- without optimization, b-with optimization.

Comparative characteristics of a magnetic field $\Delta B/B_0$ in transversal direction for different longitudinal positions as well as in various planes on an axes Z at the pole center are shown in Figs. 5-9.

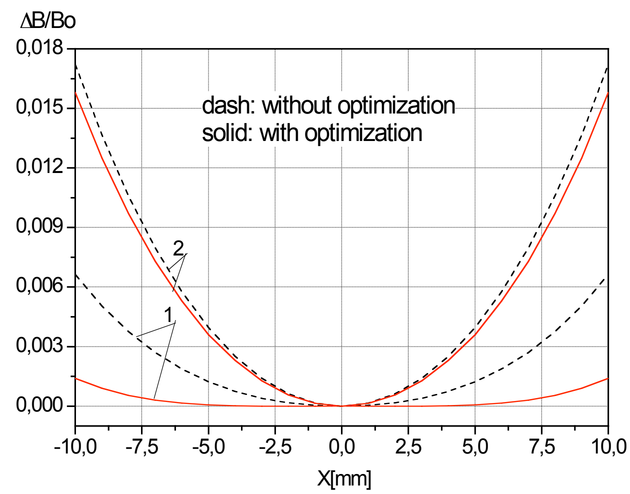

Figure 6: Relative change of magnetic field homogeneity in transversal direction for different longitudinal positions:1-Y = 80 mm, 2-Y= 46 mm corresponding to a field of 1.0 T.

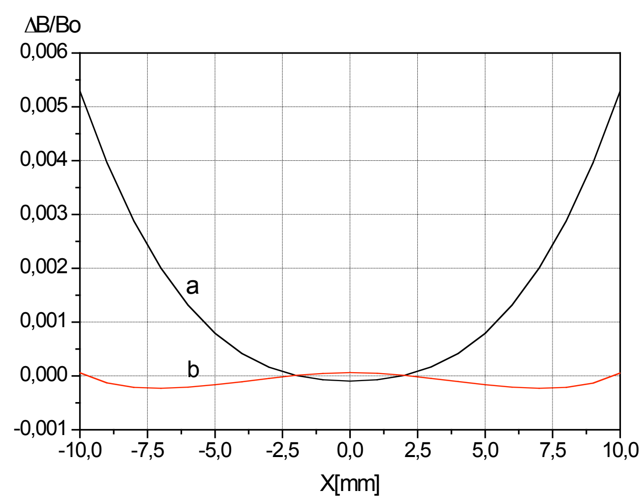

Figure 7: Relative change of the magnetic field homogeneity in transversal direction at the pole center at Z=2 mm: a–without optimization, b-with optimization.

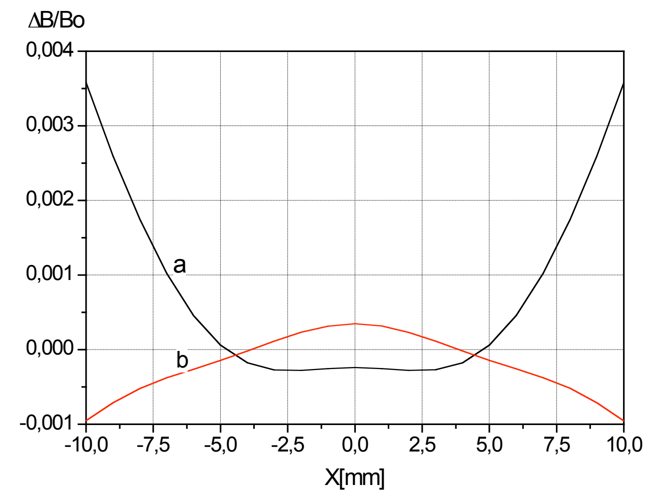

Figure 8: Relative change of the magnetic field homogeneity in transversal direction at the pole center at Z=4 mm: a–without optimization, b-with optimization.

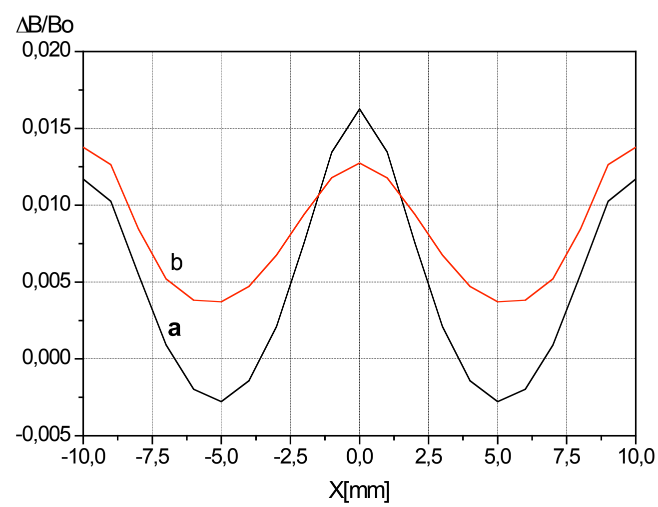

Figure 9: Relative change of the magnetic field homogeneity in transversal direction at the pole center at Z=10 mm: a–without optimization, b-with optimization.

Without optimization a broad maximum plateau (Fig.3) with a value $\Delta B/B_0 \leq 5.9\ 10^{-3}$ is in the region -10 mm ≤ X ≤ 10 mm. With optimization for the same field region a value $\Delta B/B_0$ is improved by a factor 10 and does not exceed $5.5\ 10^{-4}$.
The curves ΔB/Bo with and without optimization are being practically identical at the point Y = 46 mm (Bz = 1 T). Thus, optimization effect begins with point Y=46 mm, grows to pole center (at Y=100 mm) where it reaches the maximum.

3 Conclusion

Developed and calculated by 3D code the model of optimization of a magnetic field optimization of a permanent magnet wiggler. The preliminary, with the purpose of improvement of field roll-off, the pole width has been increased from 40 mm to 60 mm. The further improvement of a field homogeneity has been achieved by optimization of a poles profile by means of slots with various depth and width made on a pole surface. With optimization a value of field nonlinearity is improved by a factor 10 and does not exceed $5 \cdot 5\ 10^{-4}$ in the region $X \leq \pm 10$ mm.

The field map for optimized TESLA wiggler can be found at:

Field map for optimized TESLA wiggler

Acknowledgements

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