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Publication Date

1982-06-01

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Accelerator & Fusion Research Division

Submitted for the International Conference on Lasers '82, New Orleans, LA, December 13-17, 1982

PARTICLE MOTION IN THE ELF WIGGLER

Jonathan S. Wurtele and Andrew M. Sessler

June 1982

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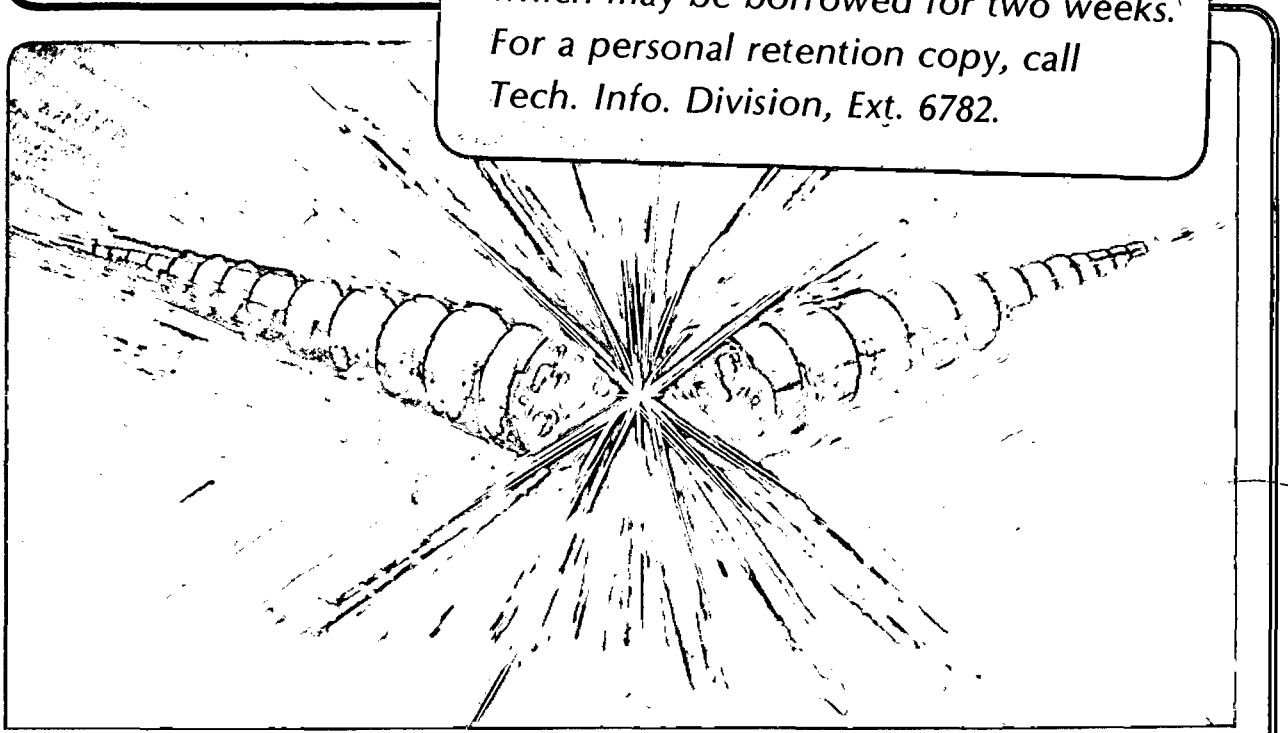

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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

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Particle Motion in the ELF Wiggler*

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June 28, 1982

Particle motion in the ELF wiggler was examined analytically and numerically. Three quadrupole focusing schemes - two quadrupoles per meter, three quadrupoles per meter and continuous focusing - were investigated. The effects of finite wiggler width was included by assuming the magnetic field in the horizontal (wiggle) plane to be

$$\vec{B} = [B_0 \sin (k_w z)(1 - \alpha x^2 - \beta x^4) - q(z)x]\hat{y}.$$

Here B_0 is the maximum wiggler field, $\frac{2\pi}{k_w} = \lambda_w$ is the wiggler wavelength, α and β model a computer generated field based on the actual wiggler design, and $q(z)$ represents the external quadrupole focusing.

In the absence of finite width effects ($\alpha=\beta=0$), the wiggler is neutral in the horizontal plane and external focusing is required to transport the beam ($E = 5$ MeV, $I = 1$ ka, $\epsilon \approx 30\ \pi$ mr-cm) through the wiggler ($\lambda_w = 10$ cm, $B_0 \approx$ 3-5 kG). This study shows continuous focusing to be superior to the other schemes considered. The external quadrupoles create horizontal betatron oscillations with

$$\lambda_h = 2\pi \sqrt{\frac{m c^2 L_Q}{e B_Q}}$$

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* This work was supported by the Director, Advanced Energy Systems, Basic Energy Sciences, Office of Energy Research, U. S. Department of Energy under Contract No. DE-AC03-76SF00098.

where B_Q/L_Q is the quadrupole gradient. When $\alpha, \beta, \neq 0$,

$$\lambda_h = 2\pi \sqrt{\frac{2m\,c^2\,L_Q}{e\,B_Q} - \alpha\left(\frac{\Omega_o}{c\,k_w}\right)^2 - \frac{3}{2}\frac{\beta}{k_w^2}\left(\frac{\Omega_o}{c\,k_w}\right)^4}\,.$$

where $\Omega_o = \frac{e\,B_o}{\gamma\,m_c}$. The wiggler provides natural small amplitude focusing in the vertical plane which is adequate to overcome the defocusing from the quadrupoles.

Many numerical calculations have been made, an example of which is shown in Fig. 1.

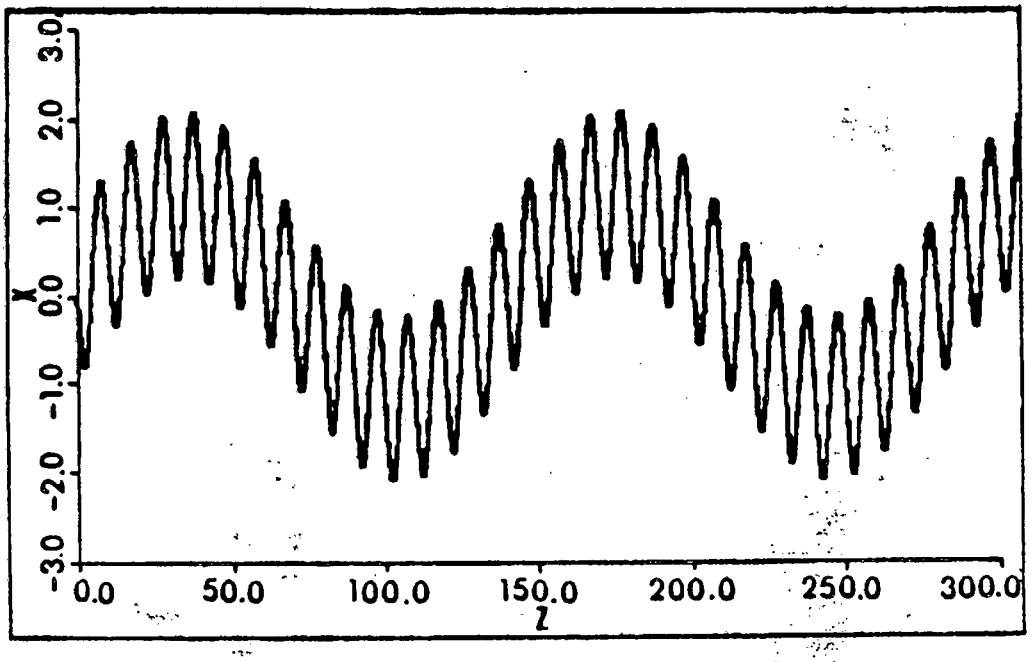

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Fig. 1. Electron orbit in wiggle plane, with $\gamma = 8$, $B_o = 5$ kG, $\lambda_w = 5$ cm, $\frac{dx}{dz}(o) = -0.50$, $\alpha = 1.08 \times 10^{-3}$, $\beta = 6.68 \times 10^{-5}$, and 30 G/cm quadrupole focusing.

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LBL-14635(ABST)

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June 28, 1982

ABSTRACT

Particle motion in the ELF wiggler was investigated numerically and analytically. A transport system was designed using continuous quadrupole focusing in the wiggle plane and natural wiggle focusing in the non-wiggle plane.

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* This work was supported by the Director, Advanced Energy Systems, Basic Energy Sciences, Office of Energy Research, U. S. Department of Energy under Contract No. DE-AC03-76SF00098.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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