**Title**

Particle Motion in the ELF Wiggler



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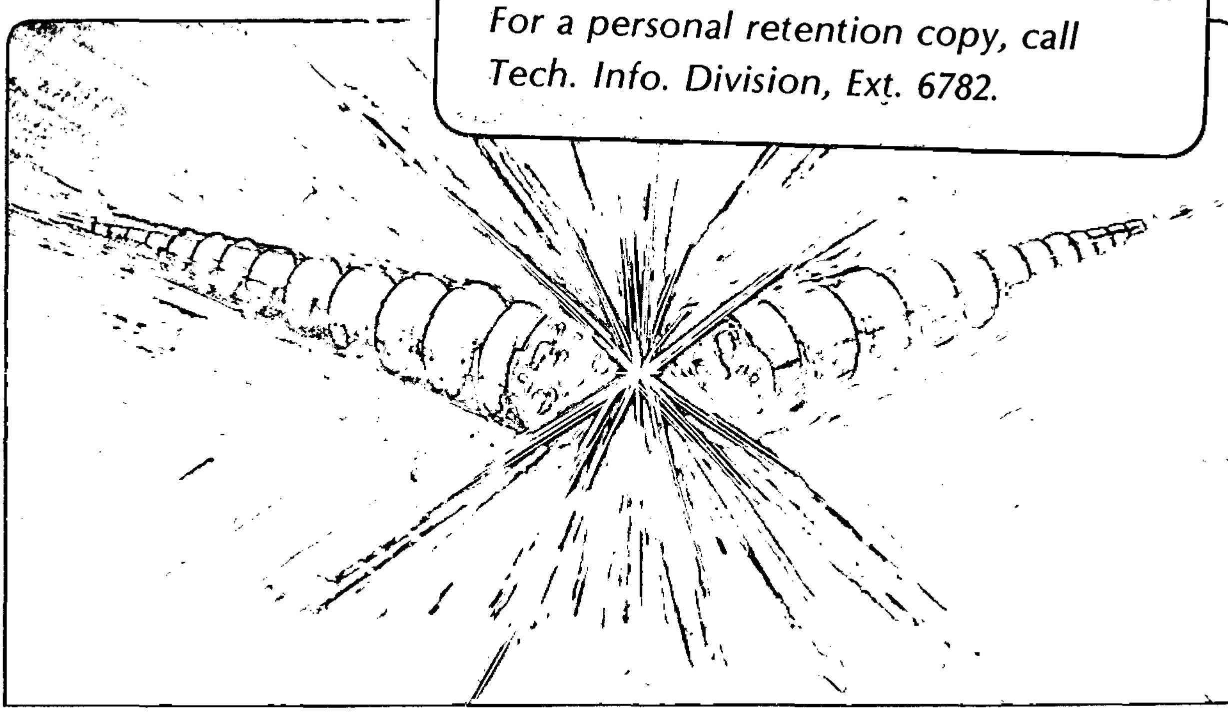



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# Particle Motion in the ELF Wiggler*

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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, $\alpha$ and $\beta$ 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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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.

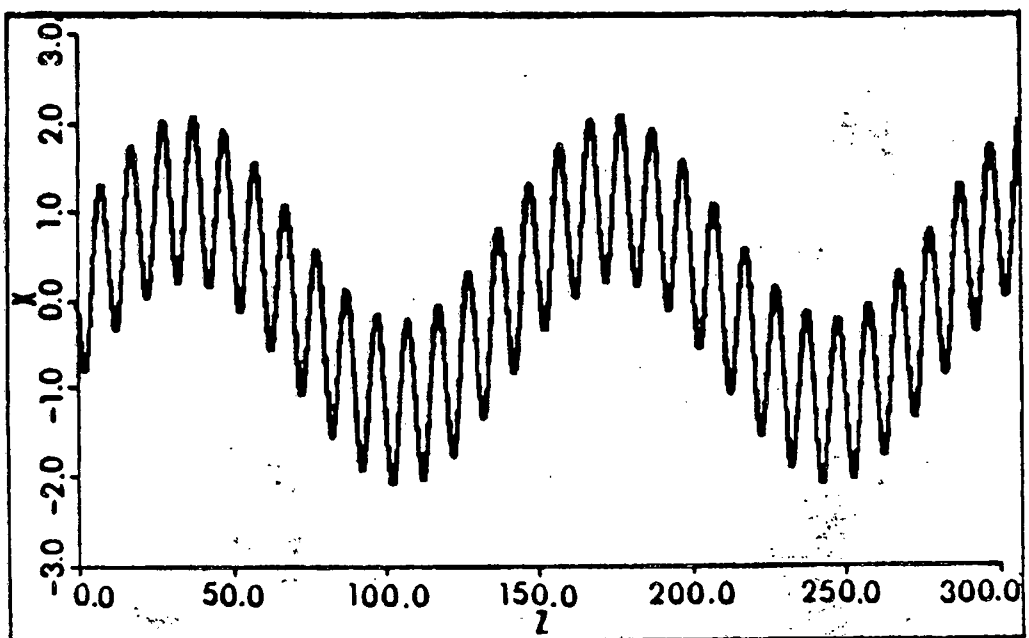


Fig. 1. Electron orbit in wiggle plane, with $\gamma = 8$, $B_0 = 5$ kG, $\lambda_w = 5$ cm, $\frac{dx}{dz}(o) = -0.50$, $\alpha = 1.08 \times 10^{-3}$, $\beta = 6.68 \times 10^{-5}$, and 30 G/cm quadrupole focusing.

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## 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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