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Author
Koike, M.

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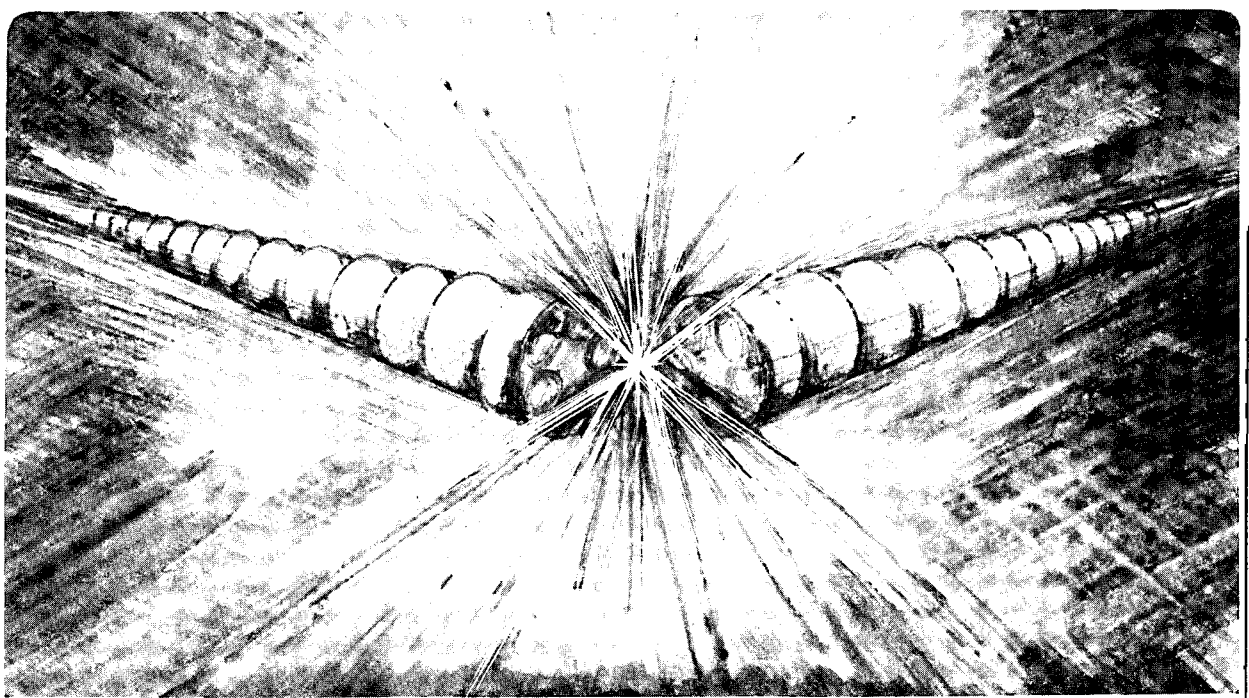

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An Efficient Subroutine for Simulating Undulator Radiation in Ray Tracing Program

M. Koike

Center for X-Ray Optics
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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AN EFFICIENT SUBROUTINE FOR SIMULATING UNDULATOR RADIATION IN RAY TRACING PROGRAM

M.Koike

Center for X-Ray Optics, Lawrence Berkeley Laboratory,
University of California,
1 Cyclotron RD., Berkeley, California 94720, USA

1. INTRODUCTION

The ray tracing method is a most effective method to evaluate the quality of spectral image formed by spectroscopic instruments. For the synchrotron light sources, the spatial and angular distributions of generated rays have some correlation with each other and vary with wavelength. These characteristics affect the evaluation of the resolution, the throughput and the spot size of monochromators. Owing to the statistical characters of synchrotron light source, those expressions should be also defined by using statistical notations. SHADOW[1] is a most widely used ray tracing programs to analyze the optical systems devoted to the synchrotron facilities and can generate rays which simulate synchrotron light sources. However, the source code for SHADOW is not available, so it is not possible to adapt the programs to other applications. Muramatu et. al.[2] developed a new ray tracing program of synchrotron light sources, in which a double Gaussian distribution is assumed to express the ray distribution properties in real and phase spaces, and Monte Carlo modelling is used to simulate spontaneous characteristics. Unfortunately, there exist in that work some inadequacies which require further attention. In this paper, we describe a final expression of the rays emitted from a undulator light source by use of same assumption and modelling and compare the spot diagrams thus obtained with those of SHADOW. The details and treatments of a wiggler and a bending magnet will be published elsewhere.

2. GENERATION OF RAYS EMITTED FROM UNDULATOR

The transverse positions(y,z) and the angles(y',z') of the rays at the center of a undulator(x = 0) is expressed as

$$y = \Sigma_y (-2 \ln u_1)^{\frac{1}{2}} \{(1-r^2)^{\frac{1}{2}} \cos 2\pi u_2 + r \sin 2\pi u_2\}, \quad (1)$$

$$z = \Sigma_z (-2 \ln u_1)^{\frac{1}{2}} \sin 2\pi u_2, \quad (2)$$

$$y' = \Sigma_{y'} (-2 \ln u_3)^{\frac{1}{2}} \sin 2\pi u_4, \quad (3)$$

$$z' = \Sigma_{z'} (-2 \ln u_3)^{\frac{1}{2}} \{(1-r^2)^{\frac{1}{2}} \cos 2\pi u_4 + r \sin 2\pi u_4\}, \quad (4)$$

where $u_i (i = 1,2,3,4)$ are random values between 0 to 1, r is a coefficient of correlation and $\Sigma_y(\Sigma_z)$ and $\Sigma_{y'}(\Sigma_{z'})$ are the horizontal(vertical) source sizes and the angular divergences[3]:

$$\Sigma_y = (\sigma_y^2 + \sigma_p^2)^{\frac{1}{2}} \quad , \qquad \Sigma_z = (\sigma_z^2 + \sigma_p^2)^{\frac{1}{2}} \quad , \tag{5}$$

$$\Sigma_{y'} = (\sigma_{y'}^2 + \sigma_{p'}^2)^{\frac{1}{2}} \quad , \qquad \Sigma_{z'} = (\sigma_{z'}^2 + \sigma_{p'}^2)^{\frac{1}{2}} \quad . \tag{6}$$

In eqs.(5)-(6), σ_y (σ_z) and $\sigma_{y'}$ ($\sigma_{z'}$) are the rms horizontal (vertical) electron beam sizes and beam divergences, and σ_p and $\sigma_{p'}$ are the rms diffraction-limited source size and the rms angular divergence of the photon:

$$\sigma_p = (\lambda L)^{\frac{1}{2}} / 4\pi \quad , \qquad \sigma_{p'} = (\lambda/L)^{\frac{1}{2}} \quad , \tag{7}$$

where L and λ are the total length of the undulator and the wavelength of the undulator radiation.

3. COMPARISON WITH SHADOW

To evaluate our subroutine, we made spot diagrams and compared with those obtained by SHADOW.To do this, we assumed the Advanced Light Source U5 undulator[3], in which σ_y = 0.330mm, σ_z = 0.063mm, $\sigma_{y'}$ = 0.030mrad, $\sigma_{z'}$ = 0.016mrad, L = 4.9 m and λ = 32.63nm. Fig.1 and 2 are spot diagrams obtained by our and SHADOW's subroutines, respectively. For the each case, the number of rays is 2000 and the times of optimization of SHADOW is 4-th. The plots, clockwise from the top left, are the y-phase space(y-y'), the z'-y'space, the z-phase space(z-z') and the y-z plane. We compared the rms values of respective parameter of rays and obtained a coincidence within ±0.6% for the positions and ±11% for the angles. The poor coincidence for angles can be explained in terms of the contribution to the outer additional rings in the y'-z' space. This work was supported by Material Sciences Division of the U.S. Department of Energy under contract No.DE-AC03-76SF00098.

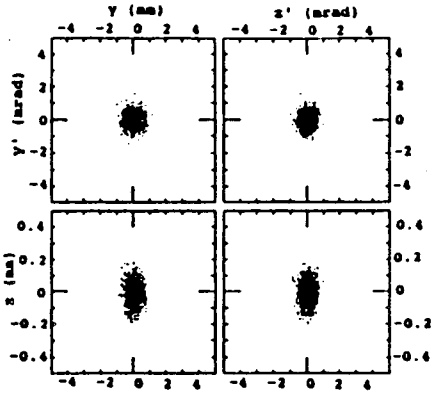

Fig.1. Undulator spot diagrams obtained by our subroutine.

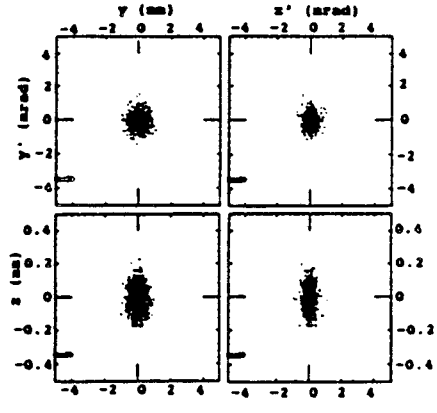

Fig.2. Undulator spot diagrams obtained by SHADOW subroutine.

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[2] Y.Muramatsu, Y.Ohishi and H.Maezawa. Jan. J. Appl. Phys. 27 (1988) L1539.

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