Current two beams piecewise undulator

V. I. R. NICULESCU[*], L. SANDRU[a], M. R. LEONOVICI[b], S. MICLOS[c], V. BABIN[c], A. VOINESCU[d]
NILPRP, Bucharest, Romania
[a]*Physics Department, Petrol Gas University (UPG), Ploiesti, Romania*
[b]*Faculty of Physics, Bucharest University, Bucharest, Romania, E-mail: lminola@yahoo.com*
[c]*Researches and Development National Institute for Optoelectronics, Bucharest, Romania*
[d]*Computer Department, "Politechnica" University, Bucharest, Romania*

A new undulator structure for free electron lasers was presented. Current PIECEWISE devices produce magnetic fields which are spatially periodic. The current has alternating directions in wires stacks. The Biot - Savart law was analytically evaluated. The structure versatility cover longitudinal undulator or wiggler design for one or two beams devices with transverse momenta.

(Received April 13, 2009; accepted April 23, 2009)

Keywords: Free electron laser, Electromagnetic undulator

1. Introduction

Free-electron lasers (FEL) imply the elaboration of compact devices [1, 2, 3]. The phenomenon of tuned coherent radiation is given by undulator the FEL principal component. The radiation is obtained by means of a relativistic electron beam injected in a periodic magnetic field produced by spatially periodic structures formed by permanent magnets or currents (undulator, wiggler). As a result a coherent radiation is generated in the Z - direction. In the new longitudinal undulators the Z magnetic field components are periodic with Z and the incoming electrons have transverse momenta. The described structure is proper for analytical evaluation of undulator magnetic components.

2. Model

The transverse cross section PIECEWISE undulator is composed 10 linear segments (Figure 1) and there are 25 wires stacks / meter (Fig. 2).

The segment wire is described by:

$$x = x_i + (x_{i+1} - x_i)\lambda, \quad y = y_i + (y_{i+1} - y_i)\lambda, \quad z = \text{constant} \quad (1)$$

E.g., the neck value is given by $h = 0.007$ m.

The transverse momentum of electrons determines the transversal characteristic of the model. In this new structure, the current in each wire has opposite sense with that of neighboring wires.

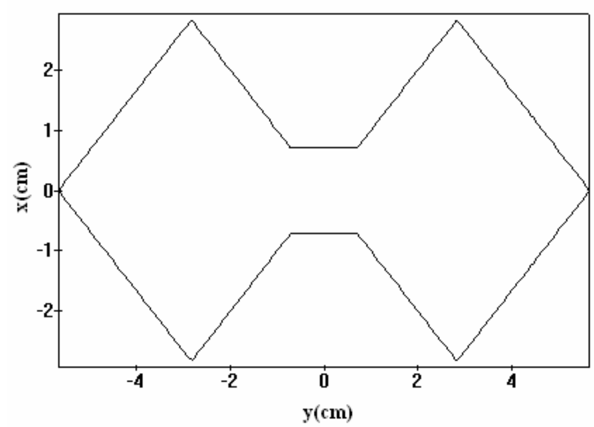

Fig. 1. The transversal PIECEWISE current undulator structure.

The magnetic field of each loop was computed with flows in the Biot - Savart law. The B_x, B_y, B_z magnetic field components for a segment of the loop are computed with formula based on integrals multiplied by the factor $\frac{\mu_0 \mu_r}{4\pi} J$, where μ_0 is the vacuum magnetic permeability, μ_r is the relative magnetic permeability, J is the current, z is wire position on Z axis, and $(x = 0,\ y = 0.028)$ are the coordinates of the point where the magnetic field components are evaluated:

$$
\begin{aligned}
B_x &= \sum_{i=1}^{10} \frac{\mu_r \mu_0}{4\pi} \int_0^1 JB_{xi} d\lambda \\
B_y &= \sum_{i=1}^{10} \frac{\mu_r \mu_0}{4\pi} \int_0^1 JB_{yi} d\lambda \\
B_z &= \sum_{i=1}^{10} \frac{\mu_r \mu_0}{4\pi} \int_0^1 JB_{zi} d\lambda \\
B_{xi} &= \int \left(dl_{yi} \bullet r_z - dl_{zi} \bullet r_y \right) / (r)^{3/2}; \\
B_{yi} &= \int \left(dl_{zi} \bullet r_x - dl_{xi} \bullet r_z \right) / (r)^{3/2}; \\
B_{zi} &= \int \left(dl_{xi} \bullet r_y - dl_{yi} \bullet r_z \right) / (r)^{3/2}; \\
r_x &= X - x,\ r_y = Y - y,\ r_z = Z - z; \\
dl_x &= -dx,\ dl_y = dy,\ dl_z = 0.
\end{aligned}
\tag{2}
$$

In the evaluation of magnetic components for a segment, do appear the integrals of type I_1 and I_2 [4]:

$$
\begin{aligned}
I_1 &= \int_0^1 \frac{d\lambda}{\left(A\lambda^2 + B\lambda + C\right)^{3/2}} = 2\frac{2A+B}{\left(4AC - B^2\right)\sqrt{A+B+C}} - 2\frac{B}{\left(4AC - B^2\right)\sqrt{C}} \\
I_2 &= \int_0^1 \frac{(M\lambda + N)d\lambda}{\left(A\lambda^2 + B\lambda + C\right)^{3/2}} = M\left(-\frac{1}{A\sqrt{A+B+C}} - \frac{B(2B)}{A\left(4CA - B^2\right)\sqrt{A+B+C}} \right) + \\
&\quad 2\frac{(2A+B)N}{\left(4AC - B^2\right)\sqrt{A+B+C}} + M\left(\frac{1}{A\sqrt{C}} + \frac{B^2}{A\left(4CA - B^2\right)\sqrt{C}} \right) - \\
&\quad 2\frac{BN}{\left(4AC - B^2\right)\sqrt{C}}
\end{aligned}
\tag{3}
$$

where:

$$
\begin{aligned}
A &= \left(x_i - X\right)^2 + \left(y_i - Y\right)^2 + \left(z_i - Z\right)^2, \\
B &= 2\left(x_{i+1} - x_i\right)\left(x_i - X\right) + 2\left(y_{i+1} - y_i\right)\left(y_i - Y\right) \\
C &= \left(x_{i+1} - x_i\right)^2 + \left(y_{i+1} - y_i\right)^2
\end{aligned}
$$

and M, N depend of the segments coordinates.

Figs. 2 and 3 show the periodic behaviour of the magnetic field components.

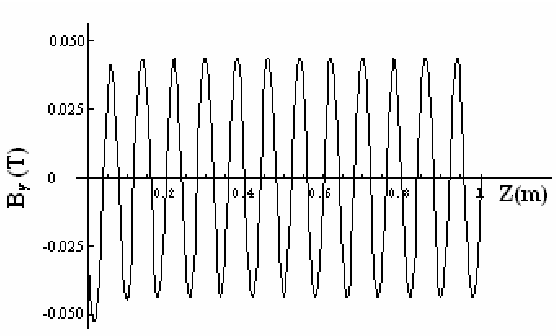

Fig. 2. The undulator magnetic field component y.

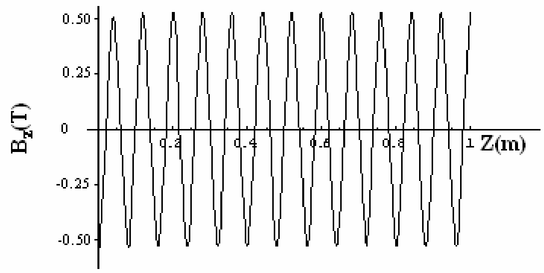

Fig. 3. The undulator magnetic field component z along Z.

The z magnetic field component is ten times greater than B_y component. The x magnetic field component is negligible. Electrons with transverse momenta are created with Kicker magnet [5].

3. Conclusions

In this paper a new model of an undulator for free electron lasers is presented. The current undulator structure is a series of PIECEWISE wires. Each wire presents C_2 symmetry. The magnetic field integrals components are analytically evaluated. So the computational time is reduced. The magnetic field is mainly longitudinal and the y component is very low. So, the electrons with transversal components injected in the undulator longitudinal magnetic field emit radiations. The model is developed for structures with two simultaneous electron beams. This new model describes the way to get two radiations beams with different wavelengths in synchrotron radiation.

References

[1] H. O. Möser, C. Z. Diago, Nucl. Instr. and Meth. in Phys. Res. **A535**, 606 (2004).

[2] B. Maragheichi, B. Farrakhi, J. E. Willett, U. H. Huang, Phys.Rev. **E61** (6-B), 7046 (2000).

[3] L. Sandru, V. I. R. Niculescu, M. R. Leonovici, V. Babin, European Particle Accelerators Conference EPAC'08, 24-27 July, 2008, Genoa, Italy, http://cape.elettra.eu/EPAC08/Publications/WEPC126.pdf.

[4] G. M. Fihtenholt, Curs of differential and integral calculus, Technical Publishing House, Bucharest, 1964 (in Romanian).

[5] R. Fabris, G. Pangon, EPAC'08, 24-27 July, 2008, Genoa, Italy.

*Corresponding author: filo_niculescu@yahoo.com