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Current SUSE Pearl Undulator

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Abstract

A new undulator structure for free electron lasers was presented. Current SUSE Pearl devices produce magnetic fields which are spatially periodic. The current structure was in the shape of wire stacks. The current has alternating directions. The magnetic field components for each wire presents symmetry with two axis. The undulator transverse cross-section SUSE Pearl was represented by two SUSE Pearls in mirror. The Biot - Savart law was numerically evaluated. The magnetic field was mainly longitudinal and easily adjusted with the current. The versatility of values cover longitudinal undulator or wiggler design for two beams devices with transverse momenta.

Key words: *Free electron laser, electromagnetic undulator*

Introduction

Free-electron lasers (FEL) implies the elaboration of compact devices [1,2,3,4,5]. The phenomenon of tuned coherent radiation is given by undulator which is 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 or 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 longitudinal and transverse momenta.

Model

The SUSE Pearl wire structures can be observed in transverse cross section. In Figure 1 The SUSE Pearl undulator structure was represented in arbitrary units .

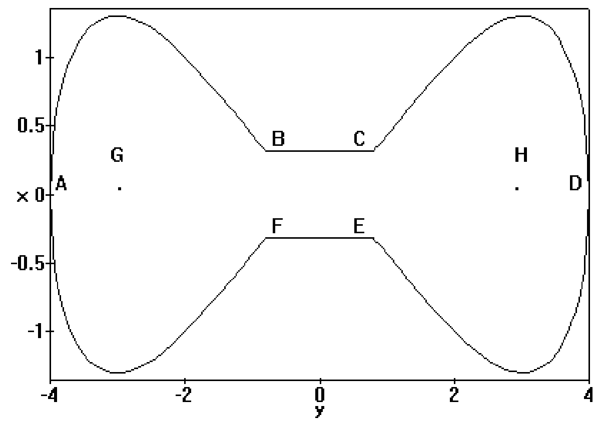

Fig. 1 The SUSE Pearl transverse cross section

The SUSE pieces are described by the following equations:

- the up branch ABCD :

$$\begin{aligned}&\left(\frac{-y}{a}\sqrt{-ay-y^2}\right)Heaviside(a+y)Heaviside(-dd-y)+\\&h\,Heaviside(y+dd)Heaviside(dd-y)+\\&\left(\frac{y}{a}\sqrt{ay-y^2}\right)Heaviside(y-dd)Heaviside(a-y)\end{aligned};$$

- the low branch DEFA :

$$\begin{aligned}&\left(\frac{-y}{a}\sqrt{ay-y^2}\right)Heaviside(a-y)Heaviside(-dd+y)-\\&h\,Heaviside(dd-y)Heaviside(dd+y)+\\&\left(\frac{y}{a}\sqrt{-ay-y^2}\right)Heaviside(-y-dd)Heaviside(a+y)\end{aligned}. \qquad (1)$$

Where $2a$ is y wire extension, dd is the distance between wires and $2h$ is the neck distance between BAF and CDE the structure lobes.

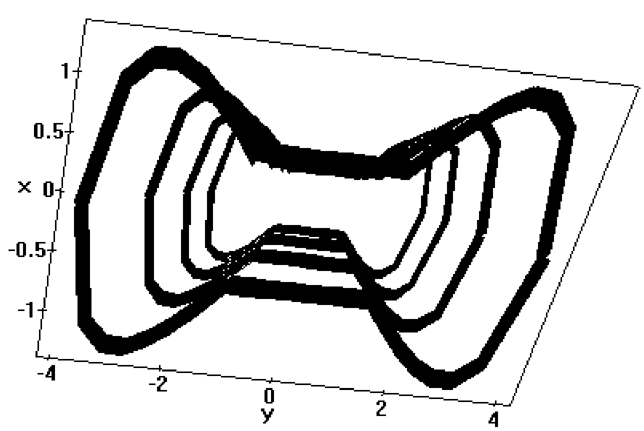

Fig. 2 Current SUSE Pearl 3D structure

The transversal caracteristic of the model was realised by electrons with transverse momentum. In this new structure the current is circulating in a stack of wires. The current in the undulator has alternating directions.

The wire magnetic field was computed by Biot - Savart law. The B_x, B_y, B_z magnetic field components (the integrals) for a wire are given by the following formula which are multiplied by the factor $\frac{\mu_r \mu_0}{4\pi} J$, where J is the current, μ_r the relative magnetic permitativity, μ_0 the vacuum magnetic permitivity and zw gives the Z wire position.

The field components implie the integrals evaluation:

$$\int_0^{2\pi} (dly \cdot rz - dlz \cdot ry)/(r)^{3/2} \; ; \; \int_0^{2\pi} (dly \cdot rz - dlz \cdot ry)/(r)^{3/2},$$

$$\int_0^{2\pi} (dly \cdot rz - dlz \cdot ry)/(r)^{3/2} \; ; \; rx = X - x,\; ry = Y - y,\; rz = Z - zw. \tag{2}$$

We have $dly = -1, dlz = 0$.

Then:

- for the up branch ABCD :

$$\begin{aligned} dlx = -\frac{dx}{dy} = &-\frac{\sqrt{-ay-y^2}\,Heaviside(a+y)Heaviside(-dd-y)}{a} - \\ &\frac{1}{2}\frac{yHeaviside(a+y)Heaviside(-dd-y)(-a-2y)}{a\sqrt{-ay-y^2}} - \\ &\frac{y\sqrt{-ay-y^2}\,\delta(a+y)Heaviside(-dd-y)}{a} \\ &+\frac{y\sqrt{-ay-y^2}\,Heaviside(a+y)\delta(y+dd)}{a} + h\delta(y+dd)Heaviside(dd-y) - \\ &hHeaviside(y+dd)\delta(dd-y) + \sqrt{ay-y^2}\,Heaviside(y-dd)Heaviside(a-y) + \\ &\frac{1}{2}\frac{yHeaviside(y-dd)Heaviside(a-y)(a-2y)}{a\sqrt{ay-y^2}} + \\ &\frac{y\sqrt{ay-y^2}\,\delta(y-dd)Heaviside(a-y)}{a} - \frac{y\sqrt{ay-y^2}\,Heaviside(y-dd)\delta(-a+y)}{a} \end{aligned};$$

- for the bottom branch DEFA :

$$\begin{aligned} dlx = -\frac{dx}{dy} = &-\frac{\sqrt{ay-y^2}\,Heaviside(a-y)Heaviside(-dd+y)}{a} - \\ &\frac{1}{2}\frac{yHeaviside(a-y)Heaviside(-dd+y)(a-2y)}{a\sqrt{ay-y^2}} + \\ &\frac{y\sqrt{ay-y^2}\,\delta(-a+y)Heaviside(-dd+y)}{a} - \end{aligned};$$

$$
\begin{aligned}
&-\frac{y\sqrt{ay-y^2}\,Heaviside(a-y)\delta(-dd+y)}{a}+h\delta(-dd+y)Heaviside(dd+y)-\\
&hHeaviside(dd-y)\delta(dd+y)+\sqrt{-ay-y^2}\,Heaviside(-y-dd)Heaviside(a+y)+\\
&\frac{1}{2}\frac{yHeaviside(-y-dd)Heaviside(a+y)(-a-2y)}{a\sqrt{-ay-y^2}}-\\
&\frac{y\sqrt{-ay-y^2}\,\delta(dd+y)Heaviside(a+y)}{a}+\frac{y\sqrt{-ay-y^2}\,Heaviside(-y-dd)\delta(a+y)}{a}
\end{aligned}
\quad , \qquad (3)
$$

where δ is Dirac function.

The $(X = 0\,, Y = 3a/4, Z)$ in SI units are the cartesian coordinates, where the magnetic field components are evaluated. The B components was evaluated with the values: $a = 0.04$ and also the half width, height neck $dd = a(3\sqrt{3})/4$, $h = \frac{dd}{a}\sqrt{add - dd^2}$.

In figures 3 and 4 the magnetic field Z dependence along the direction of one SUSE Pearl fix point (H) is given (for y, z components in relative units).

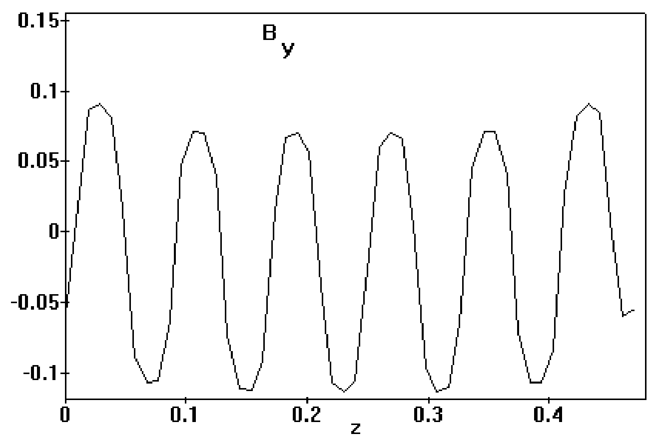

Fig. 3 The undulator y magnetic field normalised component vs. Z direction

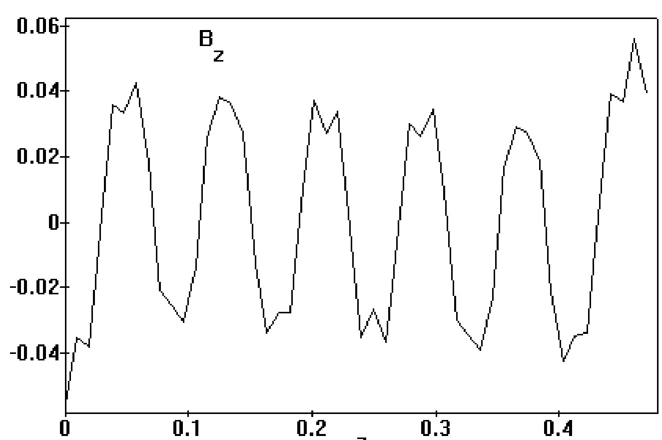

Fig. 4 The undulator z magnetic field normalised component vs. Z direction

Also we have for the magnetic conponents the relation: $B_x << B_z < B_y$. The envelope of B_y field has flat parabolic aspect. The B_z represent a half part from B_y component and has a shift to negative amplitudes. The B_x component can be neglected. In figs. 3, 4 we noticed the modulation of the magnetic field amplitudes. We underline the periodic behaviour of the *y*, *z* magnetic field components (given in relativ units). With kick fields [6] we can introduce transversal momenta in undulator field components to counter balance field shifts.

Conclusion

In this preliminary paper a new model of an undulator for free electron lasers is presented. The curent undulator structure is a series of modified SUSE Pearl wires. Each wire present a C_4 symmetry. The magnetic field integrals components are numerically evaluated. The middle magnetic field aspect transversal is and have also a important longitudinal component. The transversal aspect can be amplified by electrons with transversal components (kick field). This new model is sought for structures with two electron beams simultaneously.

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Ondulator perlă SUSE de curent

Rezumat

O nouă structură de ondulator pentru laseri cu electroni liberi este prezentată. Dispozitivele de curent perlă SUSE produc câmpuri magnetice spaţiale periodice. Structura de curent este dată de o stivă de circuite. Curentul are direcţii alternante. Componentele de câmp magnetic pentru fiecare fir prezintă o simetrie cu două axe. Secţiunea transversală a ondulatorului perlă SUSE este reprezentată de două perle SUSE în oglindă. Legea Biot - Savart a fost evaluată numeric. Câmpul magnetic este transversal cu o componentă longitudinală şi uşor ajustabil cu curentul. Polivalenţa valorilor parametrilor este utilă pentru a proiecta structuri de ondulator sau wiggler cu două fascicole cu impuls transversal şi longitudinal.