ON A BISCUIT CURRENT UNDULATOR

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Abstract
A new undulator structure for free electron lasers was presented. Current BISCUIT devices produce magnetic fields which are spatially periodic. The current structure was in the shape of wires stacks. The current has alternating directions. The magnetic field components for each wire presents symmetry with two axis. The BISCUIT undulator transverse cross-section (in arbitrary units) is a function depending directly on cosine (for x component) and sine (for y component) and inverse on the square root of the sum of forth power of sine and cosine. The z component is a constant. The Biot - Savart law was numerically evaluated. The magnetic field is longitudinal and easily adjustable with the current. The versatility of the constant parameter covers longitudinal undulator or wiggler design for one or two beams devices with transverse momenta.

INTRODUCTION
Free-electron lasers (FEL) implies 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 momentum.

MODEL
The BISCUIT wire structures can be observed in transverse cross section [4]. The BISCUIT wire is described by the following equations:

\[ x = \frac{a \cdot \cos \theta}{\sqrt{\cos^4 \theta + \sin^4 \theta}} \]
\[ y = \frac{a \cdot \sin \theta}{\sqrt{\cos^4 \theta + \sin^4 \theta}} \]
\[ zw = \text{const} \]

where \( a \) is a parameter. In Figure 1 The BISCUIT undulator structure was represented in arbitrary units.

The transversal characteristic 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 wires has alternating directions.

\[ dz = \frac{dr_x}{d\theta}; \quad dx = \frac{dr_y}{d\theta}; \quad dl = 0 \]
\[ r^2 = r_x^2 + r_y^2 + r_z^2 \]  

Figure 1: The BISCUIT wires current undulator structure.

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 multiplied by the factor \( \frac{a_2 d \theta}{4 \pi} \cdot J \):

\[ B_x \sim \int_0^{2 \pi} \frac{dl_y \cdot r_z - dl_z \cdot r_y}{\sqrt{r^3}} \cdot r_x = X - x \]
\[ B_y \sim \int_0^{2 \pi} \frac{dl_z \cdot r_x - dl_x \cdot r_z}{\sqrt{r^3}} \cdot r_y = Y - y \]
\[ B_z \sim \int_0^{2 \pi} \frac{dl_x \cdot r_y - dl_y \cdot r_x}{\sqrt{r^3}} \cdot r_z = Z - zw \]

Where \( J \) is the current, \( \mu_r \) the relative magnetic permeability, \( \mu_0 \) the vacuum magnetic permittivity, \( zw \) is the Z wire position. \( X, Y, Z \) are the cartesian coordinates of the point where the magnetic field components are evaluated.

The B components were evaluated with the values: \( a = 0.06, \quad d \theta = 0.1 \) is the distance between wires.

In figures 2 and 3 the magnetic field Z dependence along the direction of one BISCUIT fix point is given (for \( x, z \) components in relative units).

Also we have for the magnetic components the relation: \( B_x < B_y < B_z \). \( B_y \) represents a third part from \( B_z \) component. Because \( B_x \) is the tenth part from \( B_y \) component it can be neglected. In figures 2 and 3 we...
noticed the modulation of the magnetic field amplitudes. We underline the periodic behaviour of the y and z magnetic field components (given in relative units).

Figure 2: The undulator y magnetic field normalised component vs. Z direction.

Figure 3: The undulator z magnetic field normalised component vs. Z direction.

CONCLUSIONS

In this preliminary paper a new model of an undulator for free electron lasers is presented. The current undulator structure is a series of BISCUIT wires. Each wire presents a 90 degree symmetry. The magnetic field integrals components are numerically evaluated. The middle magnetic field aspect is mainly longitudinal and have also a less important transversal component. The transversal aspect was created by electrons with transversal components. This new model is sought for structures with two electron beams simultaneously.

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REFERENCES