ON A MODIFIED BERNOULLI CURRENT UNDULATOR

MINOLA R. LEONOVICI[1], V. I. R. NICULESCU[2], ANCA SCARISOREANU[3]

[1] Faculty of Physics, Bucharest University, Bucharest, Romania, lminola@yahoo.com
[2] V. I. R. Niculescu, Bucharest, Romania, filo_niculescu@yahoo.com,
[3] National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania, a_m_mihalache@yahoo.com

Received November 15, 2006

A current undulator for free electron lasers was presented. The Bernoulli structure produces magnetic fields which are spatially periodic. The structure has the shape of modified Bernoulli wire stacks. The current has alternating directions. The magnetic field components for each wire present a 90 degree symmetry. The modified Bernoulli undulator transverse cross-section was given by the relations: $x = 2 \cdot a^2 \cos(2\theta)\cos(\theta)$; $y = 2 \cdot a^2 \cos(2\theta)\sin(\theta)$; $z = \text{const.}$, a is a parameter. The Biot-Savart law in the polar coordinates was evaluated. The magnetic field was mainly logitudinal and easily adjusted with the current. The versatility of this structure was designed for two beams longitudinal undulator or wiggler with transverse momenta.

Key words: free electron laser, electromagnetic undulator.

1. INTRODUCTION

Free-electron lasers (FEL) implies the elaboration of compact devices [1, 2]. The phenomenon of tuned coherent radiation is given by the undulator 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.

2. MODEL

The Bernoulli structure can be observed in transverse cross section [3]. The Bernoulli wire is described by the following equations: $x = 2 \cdot a^2 \cos(2\theta)\cos(\theta)$; $y = 2 \cdot a^2 \cos(2\theta)\sin(\theta)$; $z = \text{const.}$, a is the distance between the fix points of the curve. In Fig. 1 the Bernoulli undulator structure in centimeters was represented.

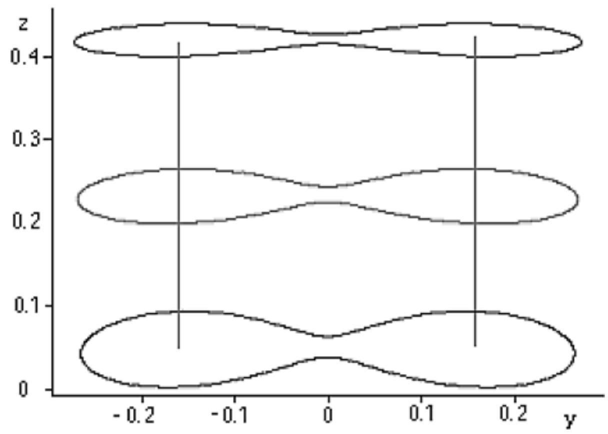

Fig. 1 – The Bernoulli wires current undulator structure.

The Bernoulli shape were replaced by modified ones with neck. The transversal caracteristic of the model was realised by electrons with transverse momenta. In this new structure the current is circulating in a stack of wires. The current in wires has alternating directions. The wire magnetic field was computed by Biot-Savart law. The *x*, *y*, *z* magnetic field components are given by the following formula with factor $\frac{\mu_r\mu_0}{4\pi}J$ for integrals :

$$B_{x_1} = \int_{\theta_i}^{\theta_f} \frac{\sqrt{2}a\cos(3\theta)\left(ZP-zw\right)}{\sqrt{\cos(2\theta)}\left(2a^2\cos(2\theta)+ZP^2+YP^2-2\sqrt{2}a\sqrt{\cos(2\theta)}\sin\theta YP-2ZPzw+zw^2\right)^{3/2}}d\theta \tag{2a}$$

$$B_{y_1} = \int_{\theta_i}^{\theta_f} \frac{\sqrt{2}a\sin(3\theta)\left(ZP-zw\right)}{\sqrt{\cos(2\theta)}\left(2a^2\cos(2\theta)+ZP^2+YP^2-2\sqrt{2}a\sqrt{\cos(2\theta)}\sin\theta YP-2ZPzw+zw^2\right)^{3/2}}d\theta \tag{2b}$$

$$B_{z_1} = \int_{\theta_i}^{\theta_f} \frac{a\left(2a\cos(2\theta)^{3/2}-\sqrt{2}YP\sin(3\theta)\right)}{\sqrt{\cos(2\theta)}\left(2a^2\cos(2\theta)+ZP^2+YP^2-2\sqrt{2}a\sqrt{\cos(2\theta)}\sin\theta YP-2ZPzw+zw^2\right)^{3/2}}d\theta \tag{2c}$$

where J is the current, zw is the Z wire position, $XP = 0$, YP, ZP – the positions where the field components are computed. Each field component are composed by the sum of three values for the θ intervals: $\left(0, \frac{\pi}{4}-\alpha\right)$ $\left(\frac{3\pi}{4}+\alpha, \frac{5\pi}{4}-\alpha\right)$ $\left(\frac{7\pi}{4}+\alpha, 2\pi\right)$, where $\alpha = \frac{\pi}{12}$ is related to the neck dimension.

In Fig. 2 the *y* magnetic field component *Z* dependence was given (normalized by $\frac{\mu_r\mu_0}{4\pi}J$ and $a = 0.04$ m).

In Fig. 3 the *z* magnetic field component *Z* dependence along the direction of one Bernoulli fix point is given (normalized by $\frac{\mu_r\mu_0}{4\pi}J$).

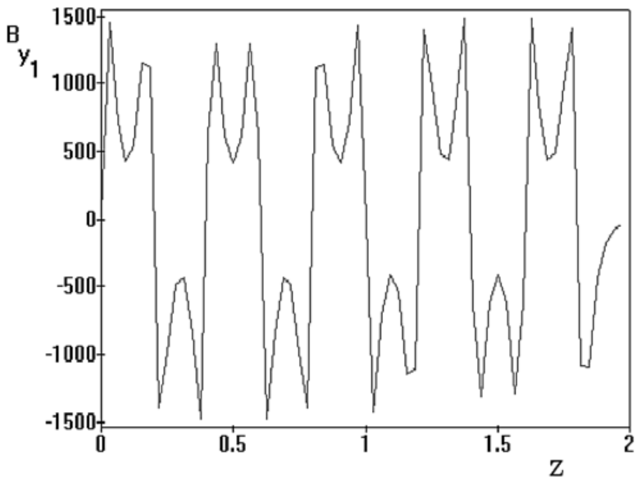

Fig. 2 – The undulator y magnetic field component *vs*. *z* direction.

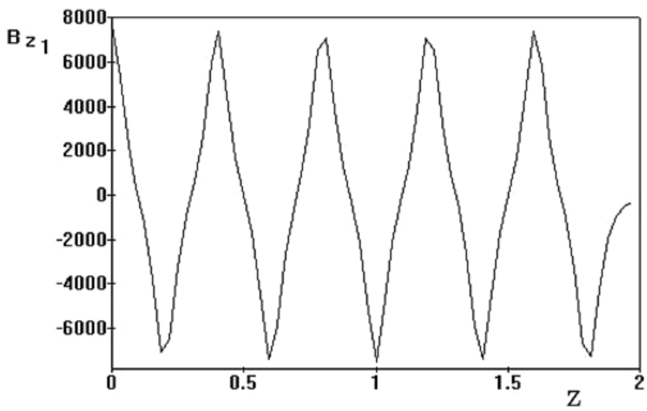

Fig. 3 – The undulator z magnetic field component *vs*. *z* direction.

The *y* field components are about 6 time less than *z* components. We noticed the periodic behaviour of the *z* magnetic field components (given in relativ units).

3. 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 Bernoulli wires. Each wire present a 90 degree symmetry. The magnetic field integrals components are numerically computed. The middle magnetic field aspect is mainly longitudinal. The transversal aspect was created by electrons with transversal components. The model is sought for structures with two beams simultaneously.

REFERENCES

1. V. I. R. Niculescu *et al.*, On a Skeleton CASSINI Ovales Current Undulator, EPAC2006, 26–30 June 2006, Edinghbourgh, UK.
2. H. O. Möser, C. Z. Diago, *Nucl. Instr. and Meth. in Phys. Res.* **A535** (2004) 606.
3. C. Mihu, I. P. Iambor, Plane Curves, Tehnical Publisher, Bucharest, 1989.