VUV-WIGGLER SCHEME WITH NON-SINUSOIDAL MAGNETIC FIELD PROFILE FOR HIGH ENERGY STORAGE RINGS

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Abstract

A planar undulator scheme with non-sinusoidal magnetic field profile along undulator axis is proposed. The advantage of this scheme is in the fact that it has lower on-axis power density as compared to that of an ordinary planar undulator, because the maximums longitudinal velocity of the electron beam does not coincide with the maximums of the magnetic fields. The spectral performance and the power density are calculated and compared to those of an undulator with sinusoidal magnetic field.

1. INTRODUCTION

There is heat load problem for designing of VUV photon beam lines in the synchrotron radiation facilities with the electron beam energies more than some GeV. When linearly polarized radiation is needed we usually use planar undulator with high K values (K = 0.934B (Tesla) λw (cm)). In this case the higher harmonics appear. The on-axis power density becomes higher and the first optical element of beam line can be damaged by unreasonable heat loading. Successful attempt to resolve this problem was demonstrated in ref. [1] using new ‘figure 8’-undulator scheme. However, it is difficult to realize such ‘figure 8’-trajectory. The purpose of this paper is to develop a new approach for obtaining linearly polarized radiation with low on-axis power density. We have found a solution for planar undulator in the frames of flexible undulator concept developed earlier by R. Tatchyn (see, for example [2,3]). As a basis the undulator scheme with non-sinusoidal magnetic field profile along the undulator axis [4,5] was used (see ref.[6], too). It was found out that the radiation properties and on-axis power density suppression depend on a degree of a ‘non-sinusoidalness’ of the magnetic field.

2. ON-AXIS POWER SUPPRESSION PRINCIPLE

It is well known that the maximum of the radiation losses of an electron is located in the regions with the maximum magnetic field values B_0. When the electron moves in the sinusoidal magnetic field, its velocity β is directed along the undulator Z-axis in these regions: $Z(\beta_{\parallel\,\max}) \approx Z(B_0)$ (see Fig.1a). As a result the maximum of the output power is directed along the undulator axis, too. If the electron moves along Z-axis outside the regions with the maximum of the magnetic field values, the on-axis power suppression appears (see Fig.1b). For the fundamental wavelength conservation it is necessary to keep the deflection parameter *K* constant.

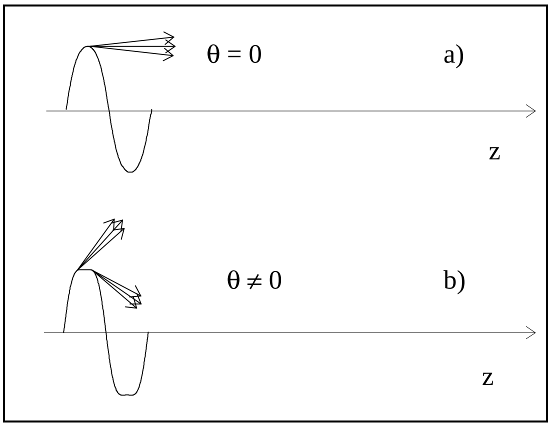

Figure 1. Electron beam trajectories and their radiation. a: sinusoidal magnetic field profile; b: non-sinusoidal magnetic field profile.

In the general case K value is given by equation:

$$K^2 = \frac{2\gamma^2 c}{\lambda_w}\int_0^T \beta_\perp^2(t)\,dt,$$

where λ_w is the undulator period, γ is the electron beam energy in units of mc^2, c is the velocity of light, $\beta_\perp$ is the dimensionless transverse component of the electron beam velocity. The integral value can be conserved in the undulator magnetic field with two maximums in the each half-period. Such non-sinusoidal magnetic field can be created by the ordinary planar undulator structure, but with the three poles per half-period [5] instead of one. In this case the central pole of each

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half-period must have a relatively weak magnetic field value.

In computer simulations the undulator magnetic structure consisting from current coils and steel poles was used. This structure was optimized for VUV beam line of Siberia-2 storage ring [7] with the following parameters: electron beam energy - 2.5 GeV, undulator period - 30 cm, magnetic gap - 5 cm and fundamental photon energy - 10 eV. 2D - computed magnetic field map, magnetic field shape B, first I and second J integrals are shown in Fig. 2. One can see that the position of the maximum longitudinal velocity of the electron differs from the magnetic field maximum one $Z(\beta_{\|\max}) \neq Z(B_0)$.

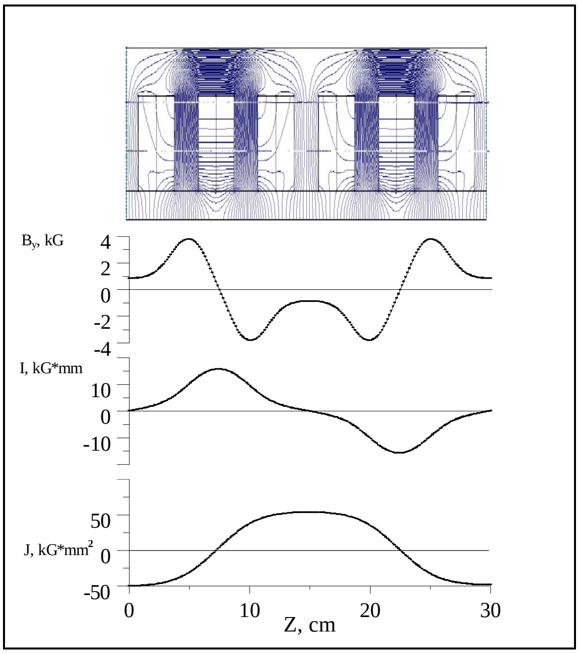

Figure 2. Magnetic field map and on-axis magnetic field B, the first I and second J integrals.

3. RADIATION PROPERTIES

The analysis of the radiation properties was made for 5-period undulator and electron beam current 0.1 A. Computer simulations of the angular distribution of the fundamental frequency in such undulator show that the fundamental intensity is very close to the correspondent intensity of the ordinary undulator with sinusoidal magnetic field profile (see Fig. 3). If the fundamental wavelength is equal to 120 nm, then its intensity is only 30% less than that of the ordinary undulator. However, the distribution of the output power generated in this type of the undulator differs considerably from the one in the sinusoidal type (see Fig. 4). The power value has a well-defined minimum on the undulator axis. In our case we have achieved the suppression value of the power radiated along the undulator axis more than 3.

More detail analysis shows that the intensity of the higher harmonics along the undulator axis is suppressed, too. Moreover, the data presented in Fig. 3,4 show that there is an optimum size of the entrance beam line aperture where the suppression effect has maximum values. Fig. 5 gives the ratio of power to fundamental flux as a function of the square hole size. The hole was placed at the distance of 10 m after

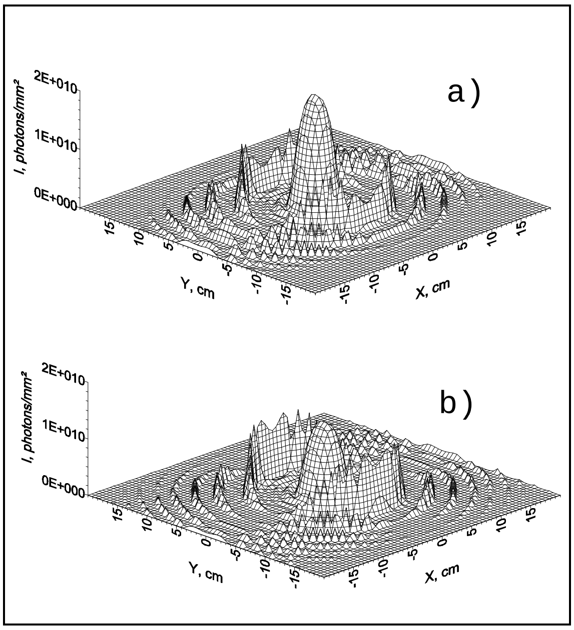

Figure 3. 10 eV - photons flux distributions. a: sinusoidal magnetic field profile; b: non-sinusoidal magnetic field profile.

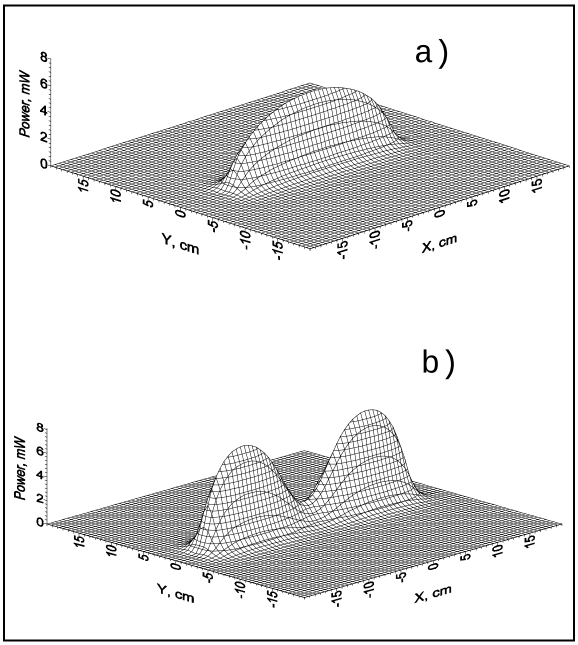

Figure 4. Power density, mW/mm^2. a: sinusoidal magnetic field profile; b: non-sinusoidal magnetic field profile.

undulator exit. One can see that the undulator with non-sinusoidal magnetic field advantage provides a considerable profit in the on-axis power density decrease and simplifies heat loading problem.

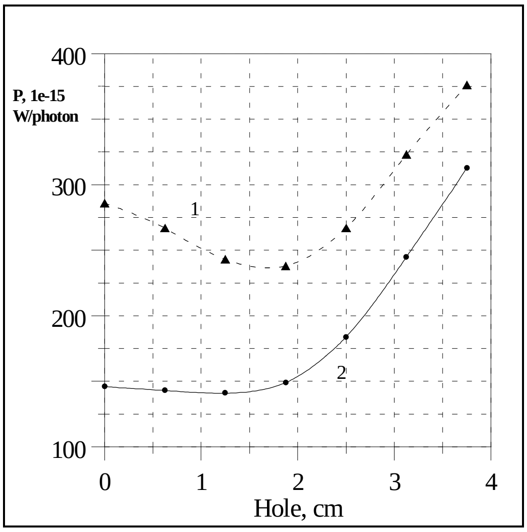

Figure 5. Power optimization. 1: sinusoidal magnetic field profile; 2: non-sinusoidal magnetic field profile.

4. SUMMARY

The proposed undulator scheme provides almost the same obtainable photon flux density of the fundamental frequency as that of an ordinary planar undulator, while the on-axis power density is much lower. The simplicity of this scheme is obvious.

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