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SIBERIA-2 EXPECTED BEHAVIOUR WITH SUPERCONDUCTING 10 TESLA WIGGLER INSERTION

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Abstract

The 10 Tesla superconducting wavelength shifting wiggler magnet is expected to be inserted into SIBERIA-2 storage ring lattice for the purpose of short wavelength x-ray production. Results of calculations of wiggler effects upon betatron tune shifts, energy spread, damping time and emittance will be presented. The paper suggests some methods of compensating the wiggler - induced beam parameter deviations. The ultimate lattice-compatible wiggler magnet field is found to be 11 T.

The 2,5 GeV SIBERIA-2 storage ring (dedicated synchrotron radiation source) designed at the Nuclear Physics Institute of the USSR Academy of Sciences Siberian Division is being constructed at the Kurchatov IAE [1, 2]. In order to have SR with λ_c near to 0.1 A the facility is to be provided with a 3-dipole superconducting wiggler magnet-wavelength shifter with a 10-12 T field.

The SIBERIA-2 magnetic lattice consists of 6 axial-symmetric super-periods, comprising each a pair of 3-meter long straight sections. The latter comprise HF cavities, electron beam injection units and insertion devices. The super-period structure is shown in Fig.1. Bending magnets B together with quadrupole lens pairs F_1D_1 and F_6D_6 serve to achromatically bend the beam. A special feature of the present lattice consists in each 30°-bending magnet being split into two identical (symmetric) 15°-bending magnets with a quadrupole lens $_2$ placed inbetween. The location of the $_2$ quadrupole lens in the achromatic bending system focus provides a simple way of controlling the minimum position of the horizontal β-function at given emittance. The working point can be corrected using the $D_2F_3D_4$ triplets. Plotted in Fig.2 are the β_x, β_z amplitude functions together with the dispersion function. The lattice is optimized to have as many insertion devices as possible, i.e. undulators and wigglers in $\eta \neq 0$, $\eta' = 0$ and $\eta = 0$, $\eta' = 0$ straight sections respectively.

The high field superconducting wiggler comprises 3 magnetic dipoles. The elliptic-shaped magnetic poles have Ni-Sn superconducting coils. There is a 180 mm distance between adjacent dipoles, the central one being displaced 11 mm off the storage ring equilibrium orbit as shown in Fig.1 bottom diagramm. The outer-directed displacement of the wiggler-on equilibrium orbit is instrumental in SR extraction. We expect to use in experiments the wiggler SR over a 3°-wide angular interval.

The total compensation of the equilibrium orbit outer-displacement effects requires two conditions to be fulfilled. First, the field should be symmetric over the shifter zone:

$$B_z(s) = B_z(-s).$$

Secondly, the field integral along equilibrium orbit should be equal to zero: $\int_{\ell} B_z(s)\,ds = 0$, with ℓ representing the straight section lenght.

There are two ways in which the superconducting wiggler affects the electron beam behaviour:

1. Additional focusing, resulting in beam oscillation frequency deviations and storage ring structural function modifications [3].
2. Radiation enhancement, resulting in energy dispersion, oscillation damping time, emittance and beam lifetime alterations [4].

The beam oscillation frequencies are shifted due to both wiggler edge-field focusing and field inclination because of the limited transversal pole width. Fig.3 plots $\Delta\nu_x$ and $\Delta\nu_z$ versus wiggler field. The 11 T field is found to produce $\Delta\nu_x = 0.001$ and $\Delta\nu_z = 0.012$. One should keep in mind the danger of coming close the $\nu_x = \nu_z$, $4\nu_x = 31$, $4\nu_z = 31$ resonances.

Sufficiently small frequency deviations, namely $\Delta\nu_x = \pm 0.025$ and $\Delta\nu_z = \pm 0.015$, can be compensated in a local way by simply adjusting the corrector-coil currents in quadrupole lens triplets of a given straight section. Larger magnetude deviation compensation would require main lens currents adjustments all over the storage ring, entailing considerable sophistications of the storage ring control codes.

The wiggler-produced β_x and β_z variations amount to about 5 per cent over the wiggler-carrying straight section and 1 per cent elsewhere. These are rather acceptable valnes.

Fig.4 plots the beam parameters in relative units versus wiggler field. The wiggler-produced enhancement of beam radiation losses would result in oscillation frequency damping time decrease and initially, at low wiggler fields, would reduce the beam emittance. However, at higher wiggler fields, the wiggler self dispersion function would emerge resulting in emittance enhancement.

The beam electron energy spread enhancement at 11 T is rather substantional. However it should not seriously affect the beam lifetime due to the 1.5 MV acceleration voltage amplitude. A further wiggler field rise might greatly enhance both the beam energy spread and emittance.

Due to the edge fields and field inclination some square-law and cubic-law non-linearity arise, i.e. the wiggler focal length and, consequently, the betatron frequences do depend upon the oscillation amplitude. To some extent this effect is handicaped by the present choice of wiggler geometry, i.e. central pole transversal displacement and transversally elongated pole profiles. The non-linearity elimination is also achieved by sextupole and octupole lenses of the wiggler-carrying straight section.

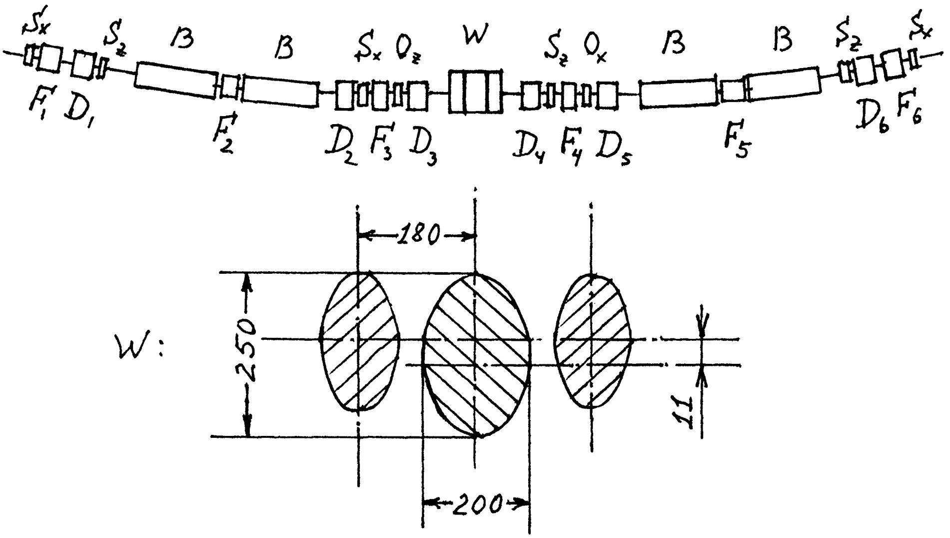
Sx
Sz
B
B
Sx Oz
W
Sz Ox
B
B
Sz
Sx
F1 D1
F2
D2 F3 D3
D4 F4 D5
F5
D6 F6
W:
180
250
11
200

Fig1

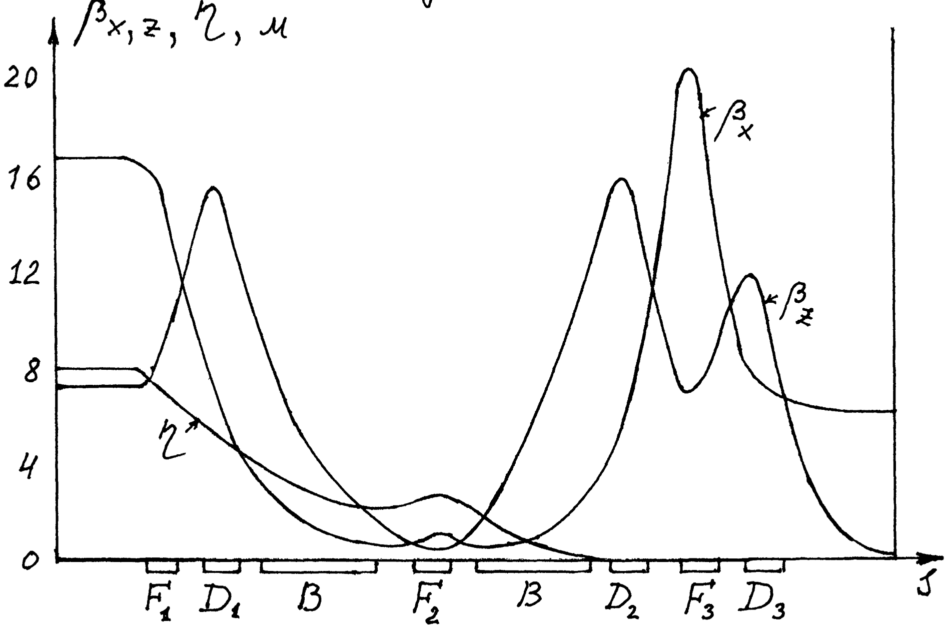
βx,z, η, μ
20
16
12
8
4
0
βx
βz
η
F1
D1
B
F2
B
D2
F3
D3
s

Fig2

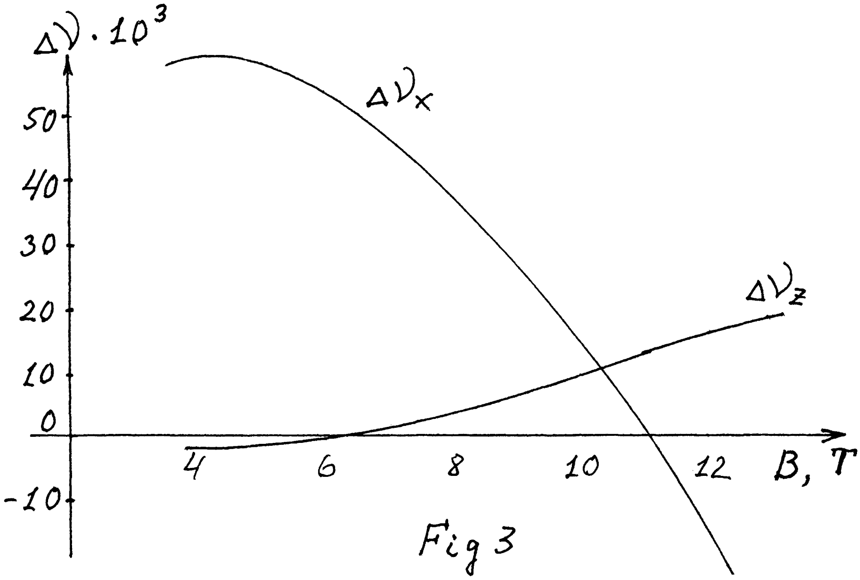
$\Delta\nu \cdot 10^3$
50
40
30
20
10
0
-10
$\Delta\nu_x$
$\Delta\nu_z$
4
6
8
10
12
B, T

Fig 3

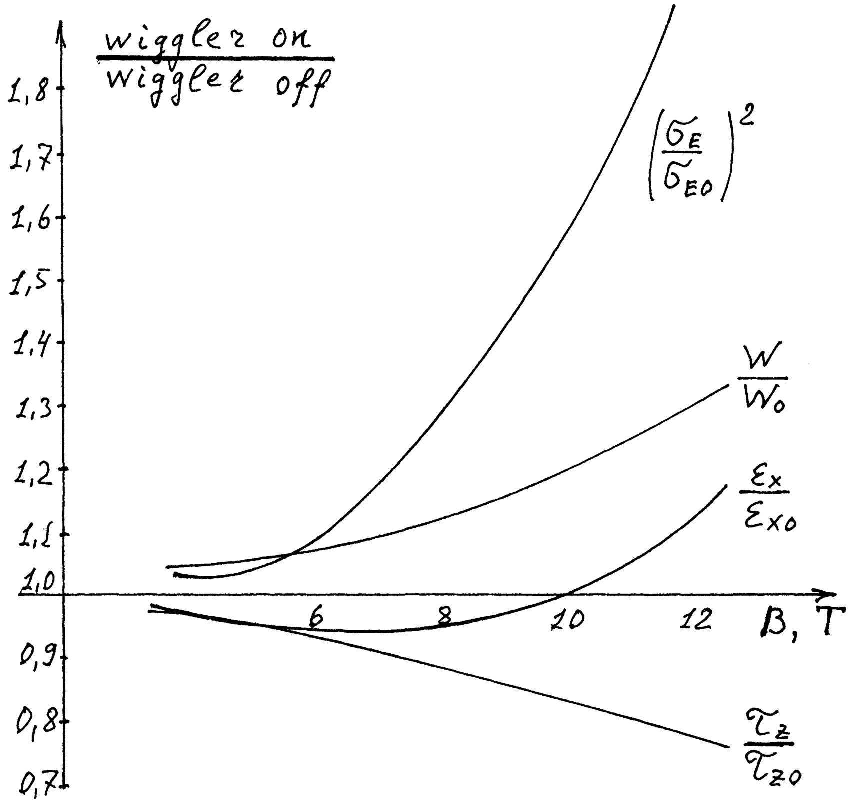
wiggler on / wiggler off
1,8
1,7
1,6
1,5
1,4
1,3
1,2
1,1
1,0
0,9
0,8
0,7
$\left(\frac{\sigma_E}{\sigma_{E0}}\right)^2$
$\frac{W}{W_0}$
$\frac{\varepsilon_x}{\varepsilon_{x0}}$
$\frac{\tau_z}{\tau_{z0}}$
6
8
10
12
B, T

Fig 4

Chromatism estimations have shown that the wiggler contribution is negligible (ξ_x = 0.17, ξ_z= - 0.37) as compared with the storage ring overall chromatism (ξ_x= -25, ξ_z = -23).

The general conclusion is that the magnetic lattice chosen for SIBERIA-2 enables one to insert a high-field (up to 11 T) wiggler in a dispersion-free straight section with storage ring performance practically unchanged.

Referances

1. A.N.Artemiev et al., Voprosy Atomnoi Nauki i Tekhniky, General and Nuclear Physics section, 1988, N 2 (42), in Russian.
2. G.N.Kulipanov, Nucl.Instr. and Meth., 1987, A261, 1.
3. E.Courant, H.Snyder, Ann.of Phys., 1958, 3, 1.
4. M.Sands, The Physics of Electron Storage Rings. An Introduction. Report N SLAC-121 (1970).

Figure captions

Fig.1. Magnetic lattice over 1/6 of the SIBERIA-2 storage ring.

Fig.2. Amplitude and dispersion functions at the superperiod middle.

Fig.3. Betatron tune shifts as a function of the wiggler field.

Fig.4. Relative variation of the beam parameters as a function of the wiggler field.