DESIGN OF AN IN-VACUUM MULTIPOLE WIGGLER FOR THE BSRF

Caitu Shi[1], Yuhui Jing[1], Hongliang Lu[# 2,3], Dashi Li[2], and Dingchang Xian[2]
[1]Accelerator Centre, IHEP, Beijing 100039, China
[2]Beijing Synchrotron Radiation Facility, IHEP, Beijing 100039, China
[3]Physics Department, Shanghai University, Shanghai 200436, China

Abstract

A new wiggler of hybrid type was designed and approved to construct for the BSRF, IHEP, China. It is a 1.8 T (while operation at the gap of 12mm) in-vacuum multipole wiggler, called IVMW-4W2, which will provide high flux in the hard X-ray region, which will mainly be used for the extreme condition experiments. The magnetic structure design of the arrays of poles and permanent magnet blocks, the vacuum system and several key technologies of in-vacuum wiggler are described in this paper. Also given is the performance of this wiggler and its compares to the current operation wiggler 3W1. This device is scheduled to install into the BSRF in autumn of 2002.

1 INTRODUCTION

Beijing Electron-Positron Collider (BEPC) is now undergoing an upgrade program, BEPC-II Project [1]. After the upgrade, the brilliance of BEPC-II will be 10 times higher than that of the current machine, BEPC-I. One of important upgrade aspects of BSRF/BEPC is to develop a new beam line for Extreme High Pressure experiments. According to the requirements of the users of this beam line, a relative high performance of the x-ray from the insertion device should be achieved to fulfill their requirements. So an in-vacuum wiggler of hybrid type was proposed [2] and designed for the new beam line in the BSRF, IHEP. It is a 1.8 Tesla (min. gap case of the wiggler) in-vacuum multipole wiggler (IVMW, named 4W2) that will provide high flux in the field of X-ray region from 20 KeV to 50 KeV. The idea of in-vacuum undulators can be traced to the early 1980's with an installation on the NSLS [3] ring and later BESSY [4]. The technology was re-examined with the installation of a 3.6 m-long device at the photon factory [5]. Then a real advance took place with the large-scale engineering development made at SPRING-8 [6].

In the second section of this contribution, the basic parameters of the IVMW, and the magnetic, mechanical designation of the arrays of poles and permanent magnet blocks are presented. The vacuum system of the IVMW, one of the key technologies of this type wiggler, is described in the third section, and also given in this section is the method to reduce the production of a wake field induced by a strongly bunched beam. The performance of 4W2 and its compares with the current operation out-of-vacuum wiggler 3W1, are presented in the fourth section. A brief conclusion is made in the last section.

Presenting and corresponding author, Email: lu@ihep.ac.cn

2 MAGNETIC ARRAYS DESIGN

To fulfil the user's the demands, high magnetic field is designed to shift the critical energy towards higher energy, and so that to extend the spectral range. This wiggler will be constructed for a beamline, in which high pressure and high temperature experiments are to be designed as primary subjects. The best photon energy for this kind of experiment is in the range of 20-50 KeV, so we need the wiggler radiation with a high critical energy i.e. we need higher magnetic field. However due to BEPC, one of a first generation machine (beam energy and current are 2.5 GeV and 200 mA, respectively), the vacuum chamber is very high, so a better way to fulfil this condition is that we bring vacuum-sealed magnets into the vacuum chamber. The aperture of this in-vacuum wiggler for an electron beam in the BEPC can be changed to satisfy various requirements of the BEPC operation. Thus, when only the wiggler X-rays are used, the desired strength of the magnetic field can be obtained by closing the magnet gap, since a plated layer for a vacuum-sealing of the magnets is very thin, as described below. This point is another advantage of the in-vacuum wiggler.

The wiggler consists of a pair of permanent-magnet arrays (Hybrid structure, period length λ_w =14.8 cm, number of periods N=11), a vacuum system (containing the arrays, and a internal chamber inserted when the wiggler opening to operate at parasitic mode, which will be described in section 3) and a mechanical frame, which controls the gap through bellows coupling.

Table 1: Basic parameters of the 4W2

Parameters	**IVMW 4W2**
Straight section length	2.228 m
Period length	14.8 cm
Number of peiods	11
Minimum gap g_{min}	12 mm
Maximum gap g_{max}	120 mm
(B_0, K) @ g_{min}	(1.8 T, 25)
E_c @ E_B=2.5 GeV	7.48 KeV
E_c @ E_B=2.8 GeV	9.38 KeV
Magnet Structure	Hybrid type
Magnet material	NdFeB (TiN-plated)
Pole material	FeCoV (TiN-plated)

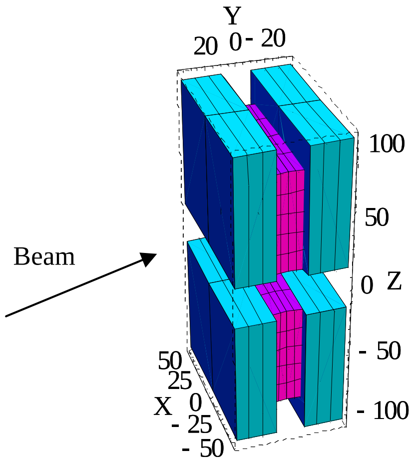

Figure 1. Diagram of half period of magnetic array of 4w2

The basic parameters of the IVMW are listed in Table 1. The structure of magnetic arrays and magnetic field distribution are illustrated in Figure 1 and Figure 2, respectively. The mechanical diagram of the wiggler is shown in Figure 3.

3 KEY TECHNOLOGIES

The key point in terms of the technology is that the delicate wiggler magnet system should be compatible with UHV. One may meet several difficulties, but with the help of experiences in Spring-8[7] and the useful discuss with the experts in the accelerator center of BEPC[8], we have good solutions which allow us to do so. (1) Difficulty from outgassing of permanet magnets, which have a porous structure. To reduce it, the magnets are to be coated with a material of TiN. (2) Difficulty from the demagnetisation of the permanent magnets during the process of UHV bakeout. To avoid this problem, special permanet magnets with very high coercivity at high temperature, in our case Nd-Fe-B 35SH (with the

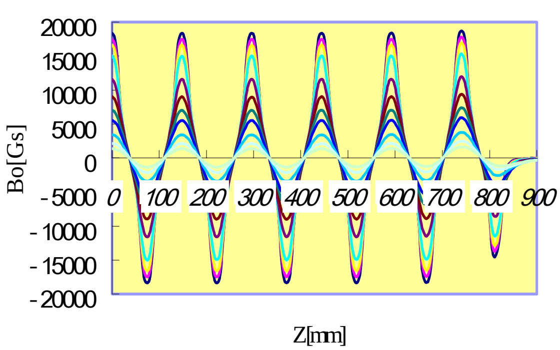

Figure 2 The magnetic field distribution at the mid-plane of 4W2, only for half array

remanent field of 1.2 Tesla and the coercivity of 21 kOe), are to be chosen. (3)Under the UHV condition, cement or glue cannot be used so we have to adopt a mechanical clamping method, the design details will be reported elsewhere [9]. (4) Difficulty from the production of a wake field induced by a strongly bunched beam because of the discontinuous of the magnet arrays' surfaces. To reduce this drawback, the gap side should be smooth, and to correct the magnetic field we have to insert small magnet chips on the back of magnets. Therefore, we have adopted flexible RF-fingers [6,7] between the wiggler magnet arrays and the entrance/exit of the vacuum chamber, see figure 3. The material for the fingers is chosen to be Be-Cu of 150 micron thick. The power generated by image beam current is not so high, however, the heat conduction is very low because of thin material. Therefore, the finger has a water-cooling channel. Of course, the magnet array has also water-cooling channels since the array is isolated in the vacuum. (5) Difficulty from the remanent magnetic field affection to the colliding beam when the facility of BEPC operated on the collide mode. Although in this case, by opening the wiggler gap, the remanent field is very small (~0.08 Tesla), it will still cause so-called impedance affection[8]. To avoid this issue, an inner vacuum chamber is designed inside the gap of the wiggler, see figure 3, which can be flexibly inserted when the wiggler operates with the maximum gap for the collide mode of the BEPC, while in the case of dedicated mode, it will be pulled out of the gap flexibly.

4 PERFORMANCES OF IVMW 4W2

The irradiance of the x-ray radiations from the 4W2 are calculated numerically as shown in figure 4. In the calculation, the initial conditions taken into account are: the horizontal ($79*10^{-7}$ m.rad) and vertical ($79*10^{-9}$ m.rad) emittance, the energy spread ($6.3*10^{-3}$) of the electron beam in BEPC ring and the absorption in an optical path. Also shown in figure 4 is the brilliance of 3W1 for comparing the performance of this wiggler to the current operation multipole wiggler 3W1 and 1W1, which is now under construction. According to figure 4, we can find that the performance of the designed 4W2 is much better than the 3W1 and 1W1, especially in the hard x-ray region of 20-50 KeV.

5 CONCLUSIONS

The first in-vacuum wiggler of China is finished designing. Hard X-ray at the range of 20-50 KeV is to be achieved for experiments. The academic committee of BEPC has approved the final conceptual design of this wiggler. It is scheduled to install into the BEPC storage ring in autumn of 2002.

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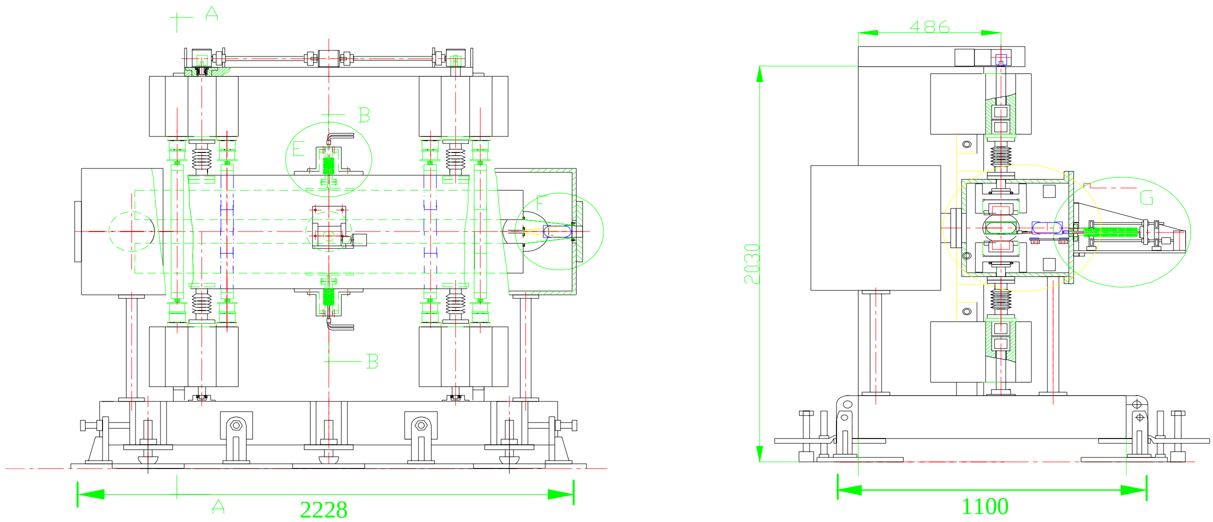

Fig. 3 Mechanical diagram of the In-Vacuum Multipole Wiggler 4W2 at the BSRF

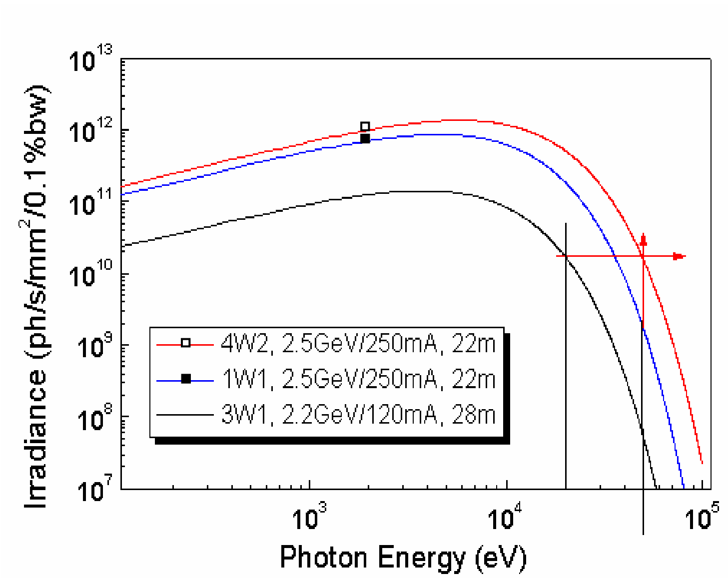

Figure 4. Irradiance calculated numerically from the wigglers, 4W2, 1W1 and 3W1. One can see that the performance of 4W2 at hard x-ray region of 20-50 KeV is much better than the others.

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