DESIGN AND CONSTRUCTION OF THE FIRST IN-VACUUM WIGGLER FOR THE BSRF

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Abstract

A new in-vacuum wiggler of hybrid type was constructed for Beijing Synchrotron Radiation Facility (BSRF) .It is a 2.0 Tesla (while operation at the gap of 12mm), which will provide high flux in the hard X-ray region and will mainly be used for the high pressure diffraction experiments. The magnetic structure design, the mechanical structure design, the vacuum system and the results of magnetic field measurement of the in-vacuum wiggler are described in this paper. Also given is the characteristics of the synchrotron radiation of this wiggler and its compares to the current operation wigglers.

INTRODUCTION

Beijing Electron Positron Collider (BEPC) is now undergoing an upgrade program, BEPCII Project. After the upgrade, the luminosity of BEPCII for high energy physics experiments will be 100 times higher than of the current machine, BEPC. 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 designed and constructed for the new beam line in the BSRF, IHEP.[1] It is a 2.0 T (minimum gap case of the wiggler) in-vacuum multipole wiggler. Which well installed into the 4th quadrant of the storage ring (named 4W2) that to provided high flux in the field of X-ray region from 20 keV to 50 keV. This device to installed into the storage ring of BEPC in autumn of 2002.

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 be constructed for a beam line, in which high pressure diffraction experiment station is to be designed as primary subjects. The photon energy for this kind of experiment to be extended 50keV, so need the wiggler radiation with a high critical energy i.e. which need higher magnetic field. However due to BEPC, one of a first generation synchrotron radiation machine (beam energy and current are 2.5GeV and 200mA, respectively), the vacuum chamber is very large, 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 strenght of the magnetic field can be obtained by closing the magnet gap.

The hybrid wiggler magnetic structure consists of Neodymium-Iron-Boron (Nd-Fe-B) blocks and vanadium permendur poles.[2,3,4] The configuration is conventional with a rectangular pole and Nd-Fe-B block array. There are period length λ_w=148mm and number of periods N=11, the range of gap is 12~128 mm.

The basic parameters of the 4W2 are listed in Table 1. The structure of magnetic arrays and magnetic field distribution are illustrated in Figure 1 and Figure 2, respectively.[5] The mechanical diagram of the wiggler is shown in Figure 3.

Table 1: Basic parameters of the 4W2

Parameters	4W2
Straight section length	2275 mm
Period length	148 mm
Number of periods	11
The range of gap	12~128 mm
(B_0, K) @ g_{min}	(2.0 Tesla, 27.6)
E_c @ E_B=2.5GeV	8.31 keV
Magnet Structure	Hybrid type
Magnet material	Nd-Fe-B (TiN- plated)
Pole material	Fe-Co-V (TiN- plated)

Figure 1: Diagram of half period of magnetic array of 4W2.

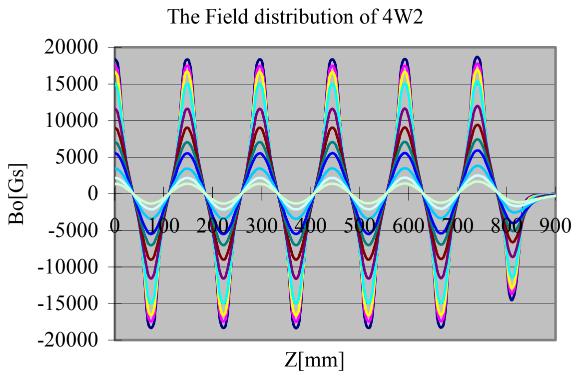

Figure 2: The magnetic field distribution at the mid-plane of 4W2 (only for half array).

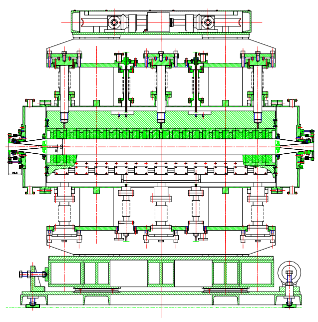

Figure 3: The mechanical diagram of the wiggler.

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 and the useful discuss with the experts in the Accelerator Centre of BEPC, we have good solutions which allow us to do so. (1) Difficulty from out-gassing of permanent magnet blocks, 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, the permanent magnets with high coercivity at high temperature, in our case Nd-Fe-B 38SH (with the remanent field of 1.25 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, see Figure 1, the design details will be reported elsewhere. (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 surface of magnet poles should be smooth, and to cover the Ni-plated Cu foil on the surface of magnet poles. Therefore, we have adopted flexible RF-fingers between the wiggler magnet arrays and the entrance/exit of the vacuum chamber, see Figure 4. 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.

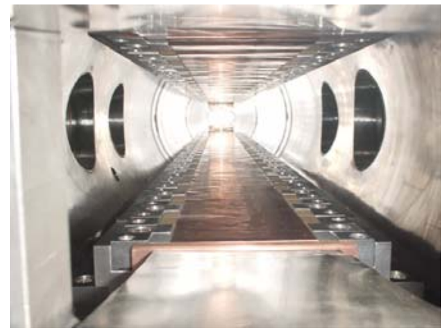

Figure 4: The magnet cover the Ni-plated Cu foil.

THE RESULTS OF THE MAGNETIC FIELD MEASUREMENT OF 4W2

The magnetic field measurement of the 4W2 in-vacuum wiggler to be used the Hall probe (Group3). The results see the figure 5 and figure 6.

gap(mm)	B0(Gs)
12.1	19966
13.5	18446
16	16450
20	14027
30	9835
40	7300
50	5580
70	3343
80	2740
100	1700
128	950

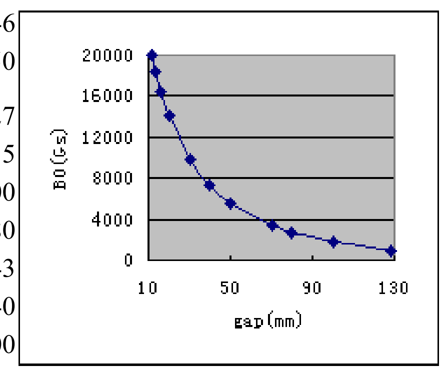

Figure 5: The curve of the magnetic field vs. gap.

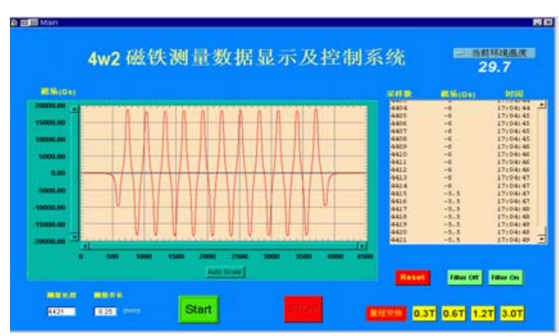

Figure 6: The distribution of the magnetic field.

THE CHARACTERISTICS OF THE SYNCHROTRON RADIATION OF 4W2

The irradiance of the X-ray radiations from 4W2 are calculated numerically as shown in Figure 7. In the calculation, the initial conditions taken into account are: the horizontal (79×10^{-8} m.rad) and vertical (79×10^{-9} m.rad) emittance, the energy spread (6.3×10^{-3}) of the electron beam in BEPC ring. Also shown in Figure 7 is the irradiance of 4W2 for comparing the performance of other wigglers to the current operation multipole wiggler 3W1 and 1W1. According to Figure 7, 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.

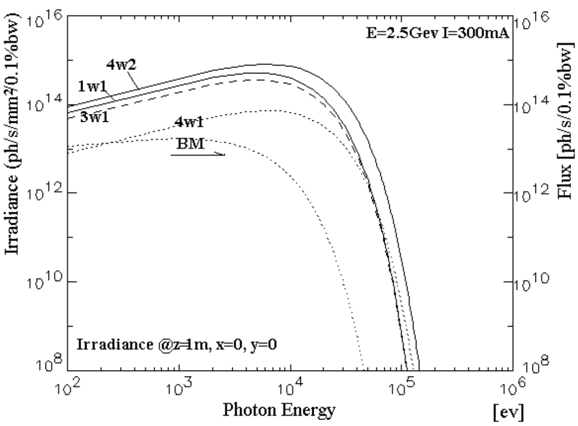

Figure 7: Irradiance calculated from wigglers at BEPC.

CONCLUSIONS

The first in-vacuum wiggler of China is finished constructing. Hard X-ray at the range of 20-50 keV is to be achieved for the experiments. It is have to install into the BEPC storage ring in October of 2002. See figure 8, 9.

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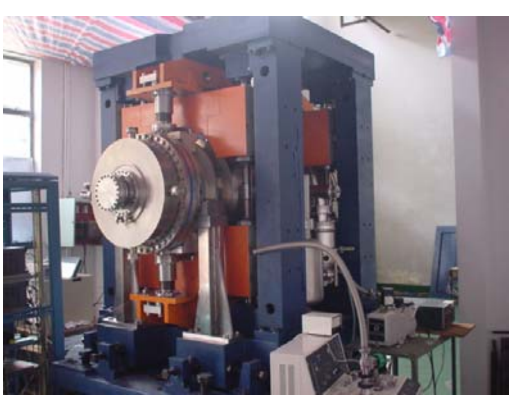

Figure 8: In-vacuum wiggler (4W2).

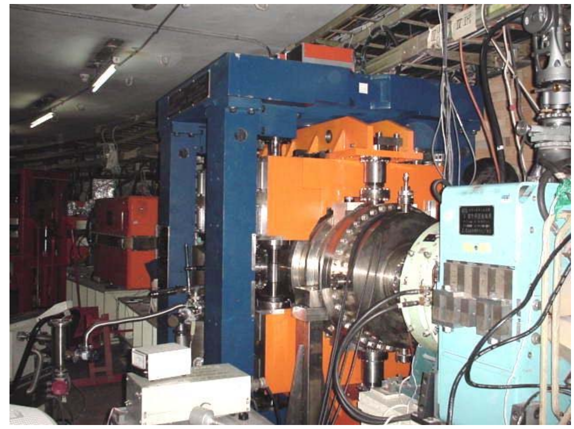

Figure 9: The in-vacuum wiggler to installed into BEPC storage ring.

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