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Preliminary Observation of the Synchrotron Radiation Spot From Wiggler Beam Line 4W1A at IHEP

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The first measurement results of the characteristics of the synchrotron radiation spot from the photon beam line 4W1A, such as the size, intensity, energy spectrum and position stability are reported in this paper. The results are quite consistent with the theoretical predictions.

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1. THE ARRANGEMENT FOR OBSERVATION OF THE SYNCHROTRON RADIATION FROM THE BEAM LINE 4W1A

On April 13, 1989, the synchrotron radiation (SR) from the front end of the beam line 4W1A was measured for the first time during the commissioning of BEPC (Beijing Electron Positron Collider). 4W1A is a photon beam line from a wavelength shifter SRW1. The wavelength shifter is a single period wiggler magnet inserted in the straight section of the storage ring to shift the SR spectrum towards the shorter region of the spectrum. This is an economic and effective method of obtaining a harder X-ray from the storage ring. According to the design, the horizontal and vertical acceptances are 1 mrad and 0.3 mrad respectively. At the end of the beam line, about 42 m from the light source, a topography experimental station is under construction.

Fig.1 shows the arrangement of the measurement. The visible part of SR going through the glass window was reflected by a plane mirror (M) onto a screen (S). Pictures of the SR spot were taken by an ordinary camera. If the mirror M was removed, the hard X-ray part of SR penetrating through a glass window could directly enter the X-ray detector. The intensity, beam position and spectrum of SR were measured by the ionization chamber or Si(Li) spectrometer.

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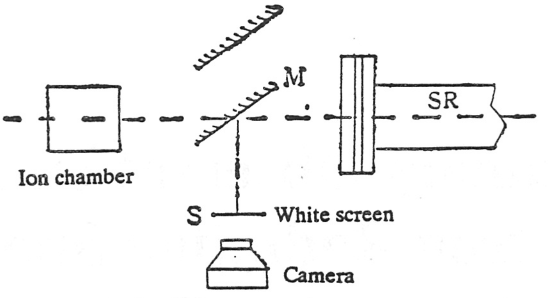

Fig.1
Arrangement of the SR spot observation
from the front end of beam line 4W1A.

2. OBSERVATION OF THE VISIBLE SPOT OF SR

Fig.2 shows the picture taken from the screen S, at electron beam energy in the storage ring E_e = 1.6 GeV, and peak wiggler magnetic field B = 1.8 T. It is seen that there are three visible light spots in the picture. The first and second spots from the left are much brighter than the third one in the right. When the current of the wavelength shifter decreases, the brightness of the left two spots do not change, but the third one becomes darker and even disappears. Also the locations of the first two spots do not change with the wiggler magnetic field, but the third one does, its horizontal

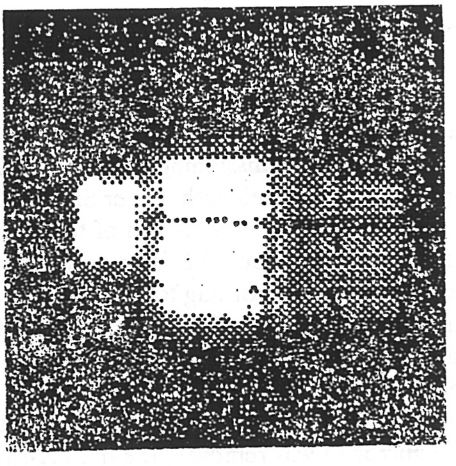

Fig.2
Visible spots of SR taken from beam line
4W1A at E_e = 1.6 GeV, B = 1.8 T.

Table 1
SR Power from 4W1A after glass window

Absorbed power in chamber (W)		Radiated power of SR (W/mrad^2 · mA)		Deviation (%)
Measured	Calculated	Measured	Calculated	
1.37×10^{-5}	1.66×10^{-5}	3.44×10^{-5}	4.17×10^{-5}	17.4

Table 2
X-ray spectrum of SR from 4W1A

Wiggler magnetic field (*T*)	Peak energy (keV)			FWHM (keV)		
	Measured	Calculated	Deviation	Measured	Calculated	Deviation
0.4	17.39	17.88	2.7%	5.04	5.30	2.3%
0.8	21.70	21.30	1.9%	7.44	8.01	7.1%

position becomes farther from the first two as the magnetic field increases. Later experiments on X-ray detection show that there are no X-ray components in the first two spots, but strong X-rays exist in the third one. It means that the third spot should come from the wavelength shifter, while the first two from the upstream and downstream bending magnets respectively. Fig.3 shows the electron track in the wavelength shifter of beam line 4W1A. A and B are upstream and downstream magnets, W is a wavelength shifter in the straight section. Electrons have a larger bend in this area

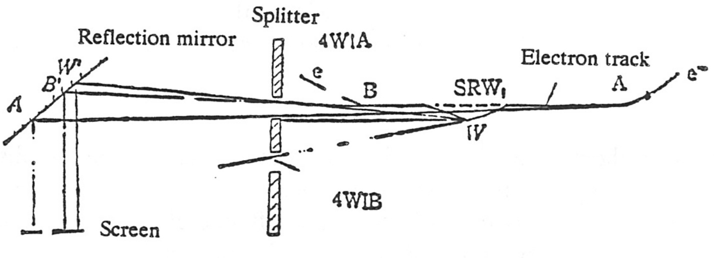

Fig.3
SR beam layout for 4W1A.

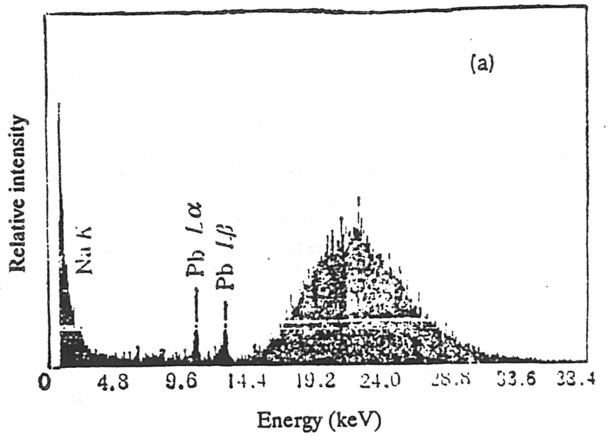

Fig.4 (a)
Measured X-ray spectrum of the SR from 4W1A;

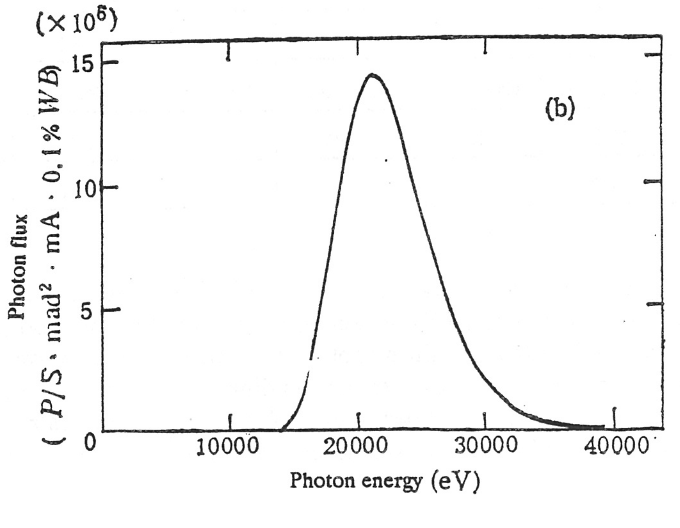

Fig.4 (b)
Calculated SR X-ray spectrum from 4W1A.

thus ejecting SR with shorter wavelengths. If we face the beam direction to observe the SR spot, as indicated in Fig.3, the upstream SR from the vicinity of A will be in the right position, the downstream SR from the vicinity of B will be in the left side of it, and at the left most place is the spot coming from W. After a mirror (M) reflection, left and right are exchanged, hence we have the picture as shown in Fig.2. Moreover, since A is farther than B to the observation site, for an exit slit of fixed height, the vertical acceptance angle for source A is smaller than that for source B, and hence the size of the spot from A should be smaller than that from B. The measured ratio of the heights from these two spots is 1.9, which is just the value defined by the mechanical components of the beam line. In fact, the vertical acceptance of the downstream SR from B depending on the size of the beam

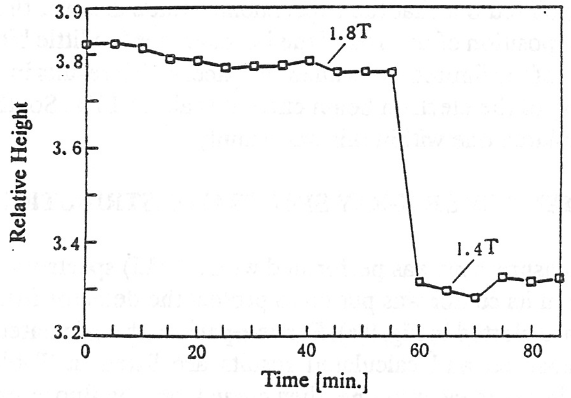

Fig.5
Stability of beam position of 4W1A.

tube is 2.98 mrad, and the vertical acceptance of the upstream SR from A depending on the size of beam tube which is nearest to SRW1 is 1.4 mrad. The ratio between them is approximately the ratio of two spot heights from the photo.

For fixed electron beam energy, the larger the wiggler magnetic field, the larger the electron bump, i.e., the bigger the deviation of source W from the central axis and the light spot from the wiggler will be farther deviated from the two spots from the upstream and downstream bending magnets (which remain unchanged no matter how the wiggler magnetic field changed). The reason that the wiggler SR spot is darker than those from the bending magnets is due to the shift of the whole spectrum forwards shorter wave lengths, in consequence the photon flux in the visible light range is reduced.

3. ESTIMATION OF THE INTENSITY OF X-RAY COMPONENTS OF SR

The intensity of the X-rays was measured with an ion chamber filled with Xenon to study the characteristics of the SR spots. Experiments show that the intensity of X-rays increases as the magnetic field of the wavelength shifter increases. The power density P of SR could be estimated easily from the ionization current of the ion chamber.

$$P = I \cdot \overline{W} / A (\mathrm{W/mrad^2})$$

Where, P -- power of SR absorbed in the chamber per unit solid angle; I -- ionization current of the chamber (A); A -- acceptance angle of the window of ion chamber to light source; $\overline{W}$ -- average energy required to produce an electron-hole pair in Xenon ($\overline{W}$ = 20.8 eV/e) [1].

The results of experiments with E_e = 1.6 GeV, I_e = 8.9 mA, B = 1.8 T and the measured I = 6.58 × 10^{-7}A are listed in Table 1.

The calculated results in the Table 1 are obtained with the help of software RADID [2], the absorptions of the observation glass window (8 mm) and the Be window (25 μm) of ion chamber when taken into consideration. The absorption coefficient of the ion chamber filled with Xenon to SR is calculated as 0.58 by RADID (in order for the power density to be obtained at the place where the chamber is set up). The results between experimental and calculated values agree with each other within 17%. It should be pointed out that the experimental value is lower than the theoretical one, the main reason is that the position of the axis of the ion chamber is a little bit lower than that of the photon beam line, because of the limited experimental space, which results in an error of about 20%. In addition, the uncertainty of the electron beam current is about 10%. So, the experimental result is consistent with the calculated one within this uncertainty.

4. DIRECT MEASUREMENT OF SR X-RAY SPECTRAL DISTRIBUTION

The SR spectrum measurement was performed with a Si(Li) spectrometer. A lead (Pb) cover with a pin-hole ≤ 0.2 mm in its center was put on to protect the detector from counting saturation. The experimental results are plotted in Fig.4(a). For comparison the calculated spectra are also given in Fig.4(b). Both the measured and calculated results are listed in Table 2. There are some characteristic X-ray lines in the measured one, they come from the fluorescence of lead and glass.

5. STABILITY OF BEAM POSITION

Long term stability of the beam position is quite important. Usually the experimental station is far from the source point, say, 20--40 m, the vertical acceptance is rather small, so any displacement of the electron beam at the source point will result in a bigger change of the light spot. A split chamber [3] designed and made by ourselves was used to measure the position stability of photon beam 4W1A and the results are shown in Fig.5. The height of a collective electrode in the split chamber is d = 21 mm. The distance between the two electrodes is 28 mm and the differential sensitivity is 2.08 μm/mV. Fig.5 shows the beam position of SR is rather stable, its vertical displacement is less than 40 μm, if the magnetic field of wavelength shifter keeps constant. When the magnetic field of wavelength shifter changes from 1.8 to 1.4 T, an abrupt jump of beam position appears, while the magnetic field remains at a lower level and the position of the SR spot becomes stable again.

6. SUMMARY

The preliminary observation of the SR spot from the front end of beam line 4W1A shows that both the measured and calculated results are in agreement and the design and installation of the beam line are successful. Further improvements are needed. The machine BEPC is in the phase of commissioning, the operation mode, the close orbit parameters etc. are subject to fine adjustment, correspondingly the beam line needs further alignment, we believe our experience in the SR spot measurement will be helpful in the future work.

ACKNOWLEDGMENT

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