MEASUREMENTS OF RADIATION DOSE LEVEL AROUND 3W1 BEAMLINE OF BEPC

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Abstract

This paper describes the possible radiation sources and their characteristics around 3W1 beamline of Beijing Electron-Positron Collider (BEPC). A homemade monitoring system is used to measure the dose level around 3W1 beamline. The obtained results show that the radiation field depends on the BEPC operation status. During the normal storage operation, the radiation field is a slowly changing field close to a constant. The dose level is proportional to the beam intensity. However when electrons are injected into the storage ring, the radiation field becomes a fast changing field with a very high dose level. Furthermore our results indicate that accidentally the beam loss occurred near to 3W1 beamline, which led to the fast increase of dose level.

Keywords: Radiation, Dose, Beamline, Electron-Positron Collider

1 INTRODUCTION

In the upgrade program of the BSRF, a new permanent-magnetic wiggler, two beamline and related experimental stations have been installed and operated since the end of 1996. 3W1 is a permanent-magnetic wiggler installed at quadrant Ⅲ of the BEPC storage ring. The operation parameters are as follows: total length of straight section, 7.5m; period number, 5; gap, 4.3; magnetic field, 1.43 T; critical energy, 4.6keV; deflection coefficient, 40. It can be operated in either the dedicated or parasitic mode of the BEPC. The photon beam from the front end is separated into two beamlines at an angle of 6.3 mrad. 3W1A is a white-radiation beamline with an acceptance of 1 mrad, and -1 mrad with respect to the wiggler axes. 3W1B is a monochromatic focusing soft X-ray beamline with an acceptance of 1 mrad. and +5.3 mrad with respect to the wiggler axes.

However the design of 3W1 beamline lacked of the consideration of radiation shielding and only had a safety shutter. When the experiment is done and the safety shutter is open, the dose level near 3W1 beamline is very high. After the operation of 3W1 beamline. The relative high dose level is reduced by means of adding a lot of local shielding.

Our work aims at determining the radiation field distribution of 3W1 beamline in order to determine the possible radiation sources and to take appropriate protection measures. In addition, the field distribution is significant for other beamline of BEPC designs too.

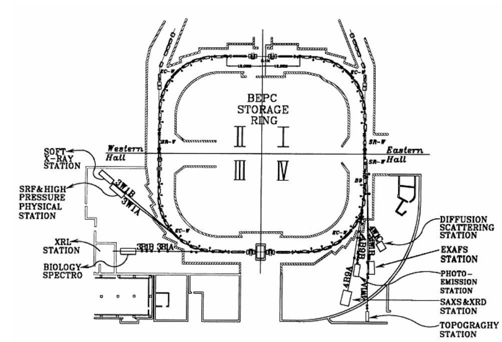

Figure 1: Schematic of the BEPC storage ring

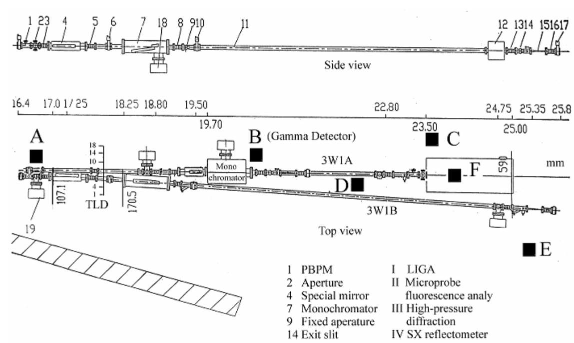

Figure 2: Layout of the new beamline from wiggler 3W1

2 RADIATION SOURCES AND CHARACTERISTICS

The radiation field around 3W1 beamline behaves very differently depending on the operation status of the storage ring. At the beam injection stage, the field is a transiently changing field occupying a small space with a high radiation dose level while it is a slow changing field close to a constant field at the normal beam storage stage. The radiation dose level at the normal storage stage is proportional to the beam intensity in the storage ring. A sudden beam loss can result in great increase in dose level. The following section gives a more detailed description about the radiation dose level at varieties of operation stages.

2.1 Beam lost during electron beam injection into storage ring

3W1 beamline locates at the west experimental hall of the synchrotron radiation facility that is near to the positron injection spot. The thickness of the concrete shielding between the beamline and the storage ring is 50 cm (see Figure 1). At the injection stage, a lot of injected electrons are lost in the vicinity of the injection spot due to the injection efficiency. Therefore the dose level around 3W1 beamline which is behind the positron injection spot is obviously higher than other experimental halls during the positron injection. However the electron injection has little influence on the dose level.

2.2 Gas bremsstrahlung

The gas bremsstrahlung is produced by the interaction of the storage ring positron or electron with residual gas molecules in the ring vacuum chamber. Such interactions are one of the sources of stored beam losses that result in beam decay. Gas bremsstrahlung interactions take place all around the storage ring, But are a particular in the straight sections for the Insert Device. Gas bremsstrahlung is produced in a very narrow beam (1/γ) that sums for the entire section length. The 3W1 Insert Device straight sections are 7.5 m in length. The characteristic scattering angle of the gas bremsstrahlung is [1]:

$\theta = 0.511 \times E^{-1}$ (radian),

E is the electron energy within the storage ring in unit of *MeV*

The radiation dose equivalent rate (*DER*), in the forward direction due to the direct gas bremsstrahlung beam is proportional to[2]:

$$DER \propto \frac{E_0^{2.67}.ipl}{d(l+d)}$$

E_0: the storage ring energy;
i: the storage ring current;
P: the storage ring pressure;
l: the length of the effective straight section;
d: the distance from the end of straight section to the observation point.

The gas bremsstrahlung produced in the straight section migrates along the beam pipe. During the migration, it radiates the pipe shell and the optical components inside, which produces the second radiation. The mixture of the primary and the secondary radiation can penetrate the pipe shell and the shielding wall (50 cm) forming a radiation field with fairly high dose level.

2.3 Sudden beam lost within storage ring

The physical reason for sudden beam loss is too complex to discuss. Here only the dose measurement results are given.

3 EXPERRIMENTAL

The radiation field around 3W1 beamline was studied under a variety of storage ring operation and shielding conditions. The dose level at the sampled spots was recorded by our monitoring system consisting of γ-monitor and Digital Data Logger All the instruments are introduced as follows:

The homemade γ-monitor adopts a cylinder ionization chamber aerified argon gas as the detector. The sensivity is 2.58×10^{-10} C/Kg Pulse. The output is a current circle being of 20 mA in intensity and 800 μs in time interval. This output form has a strong resistibility to electromagnetic disturbances.

The CPU of the Digital Data Logger (DDL) is a high speed CMOS chip produced by Motorola Company. There are 16 channels at the DDL inlet. The input is carried out by means of photoelectric coupling which provides a reliable signal transmitting among the monitors at a variety of distances. The software programmed in assembly and C language can realize the functions such as data acquisition and storage for γ-monitor, parameter setting, plotting, printing and alarming and so on. The memory (RAM) inside the DDL can reserve the data acquired within ten days.

The γ monitors are located at A, B, C, D, E and F points around 3W1 beamline in the forward direction, as illustrated in Figure 2. The dose equivalent rate at several points were measured under three operation stage of the storage ring: injection stage, storage stage, beam loss stage. The measurement result are listed in Table1:

Table1: Dose equivalent rate around 3W1 beamline

Stage / Position	Injection	Storage	Beam Losss
A	12.5	8.0—2.0 (50—20mA)	52.0
B	3.0	1.3—0.6 (65—20mA)	30.0
C	0.8	(0.3—0.16 (60—20mA)	32.0
D	6.0	4.0—1.2 (65—20mA)	96.0
E	1.0	0.32—0.16 (60—20mA)	20.0
F	>12900	>12900	

Unit: uSv/hr

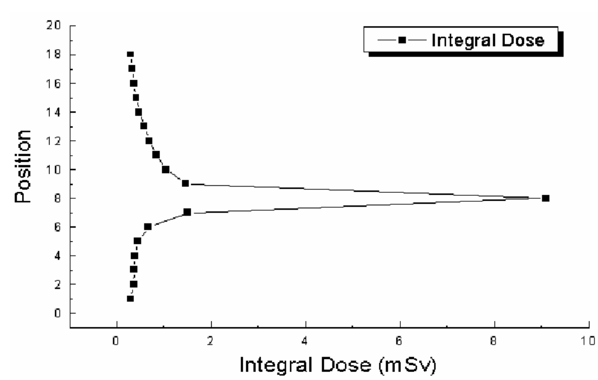

Figure 3: Integral dose vs position

A typical figure of variety of the beam current in storage ring is presented in Figure 4.

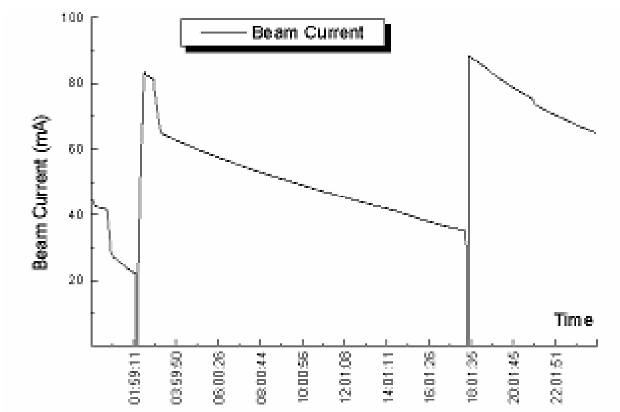

Figure 4: Beam current vs time

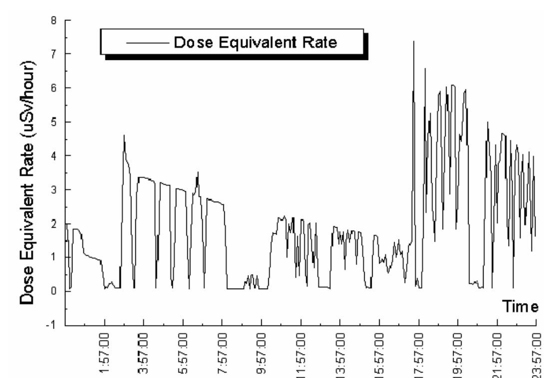

Figure 5: Dose equivalent rate vs time

Figure 5 demonstrated the detection result of the dose rate at A spot, which correspond with the beam current in Figure 5. There are a lot of downward hackles in the figure, these are caused by that, when the experimental personal shut off the safety shutter , the dose rate decreased sharply. According to this figure, the beam current decreased slowly during the beam storage stage and the dose rate decreased slowly too. Accidentally the beam loss occurred near to 3W1 beamline, which led to the fast increase of dose rate.

The thermoluminescent dosemeter used in the experiments is a ^{7}LiF-TLD produced by China Nuclear Radiation Monitoring Institute. Its energy response is from 30 KeV to 4 MeV within the measurement range between 0.1 μ Sv and 12Sv, [4]. In our experiments the TLD is used as a relative measurement tool which gives the accumulated γ-dose value at a specified position during a time period. As shown in Figure 2, TLD chips were arranged behind the light target A point, in the level of the beamline, which is vertical to the beamline, the distance between every two chips is 4.6 cm. The cumulative was detected during 1998/7/1/9:00--7/4/18:00. Figure 3 presents the result and show that the cumulative dose is higher at the point near the beamline.

4 CONCLUSIONS

Finally, following conclusions can be drawn from our measurement results:

- The dose level along the exit direction of 3W1 beamline relates to the operation stage in storage ring and the exit angle. Specially when in injection stage The year integral dose can reach the limit value 3/10 allowed for radioactive personnel within a certain angle scope if the safety optical shutter is open and the Wiggler is inserted. This angle scope is called controlled area which boundary should be labelled by a radiation mark or equipped with a shielding net.
- Under the synchrotron operation, the dose equivalent rate near to the light target along the direction of the observation window can reach 8.0 μ Sv/hr if the safety shutter is open and Wiggler is inserted. Therefore it is absolutely forbidden to observe the facula with eye in the direction along the observation window.
- Under the synchrotron operation, the dose equivalent rate has exceeded measure range (12900 μ Sv/hr) of γ-monitor inside the experimental hutch which will` exceed the limit value allowed for radioactive personnel if the safety shutter is open, photo shutter is off, and Wiggler is inserted. In this case, nobody is allowed to work in the hutch.
- During the beam injection, the measured maximum values of the dose equivalent rate in 3W1A work area C spot and in 3W1B work area E spot are 0.8 μ Sv/hr and 1.0 μ Sv/hr respectively. The radiation dose level is very high relatively. Therefore we suggest all the working staffs leave the 3W1 work area during the beam injection.
- Under the synchrotron operation, in the normal beam storage stage, the measured maximum values of the dose equivalent rate in 3W1A work area C spot and in 3W1B work area E spot are 0.3 μ Sv/hr and 0.32 μ Sv/hr respectively. Both values are under the safety dose level and staffs are allowed to work in 3W1 work area.
- The area near to the observation window of the light target is a high radioactive area. Furthermore it directly faces to 3B1 area which radiation dose level is very high too. The observation window should be shielded with Pb plate in general case.
- The radiation dose level at the vacuum pipeline outlet behind the hutch of 3W1A is relative high for the scattering experiments. More shielding should be added in the area.

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