DESIGN, MANUFACTURE AND OPERATION OF THE BEAM SPOILER FOR POSITRON TARGET PROTECTION*

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Abstract

In order to produce positrons, intensive pulsed electron beam is used to strike on a tungsten target. The energy deposition is distributed non-uniformly over the target, leading to a mechanical stress. As a result of large thermal gradient, the target could be potentially damaged. To avoid the target destruction, the peak energy deposition density (PEDD) in the target should be well below the critical limit (35 J/g) based on the SLAC operational experience. With an expected primary electron spot size on the target of SuperKEKB positron source, the PEDD will exceeds the limit. We will introduce a beam spoiler to enlarge the spot size by multiple scattering in thin beam screen and aluminum plate. It reduces the PEDD down to half of the limit. This paper describes the design of the spoiler and the beam screen system used in the positron beam commissioning of SuperKEKB positron source started in 2014.

INTRODUCTION

SuperKEKB requires an intensive beam with a large number of positrons, which is generated by a 3.5 GeV primary electron beam with a charge of 20 nC/pulse and the frequency repetition rate is 50 Hz [1]. The pulsed electron beam distributes the energy non-uniformly over a tungsten target. A mechanical stress appears due to the large thermal gradient during each pulse, which could potentially destroy the target. Such kind of target damage has been experienced at SLAC [2]. After a series of experiments, the peak energy deposition density (PEDD) has been described as the parameter to evaluate the safety margin and to determine the incident beam size to avoid the target damage. The threshold value of the PEDD is about 35 J/g. The detailed study of correlation amount electron beam spot size, target PEDD and positron yield has been discussed in the paper [3]. One of the conclusions is that a spot size of 0.7 mm is an optimum value considering the safety margin of PEDD and positron yield reduction. For SuperKEKB, at the upstream of the positron target, as we can see from the Fig.1, there are pulsed quadruples for the beam focus purpose. The pulse quadruples could mis-focus the primary electron beam leading to extremely small spot size. In order to make sure the primary electron beam strike on the positron target with a PEDD lower than 35 J/g, a protection spoiler needs to be placed between the focus magnet and the target. The spoiler should be placed close to the pulsed quadruple to prevent to be destroyed by the extremely small size electron beam. The beam spoiler is made of aluminum attaching with a screen monitor who can help us observe the beam through view port. In the following section of this paper, the spoiler design and assembly will be introduced. Furthermore, the spoiler and target alignment would also be discussed. In the final section, some early stage spoiler test with electron beam will be presented.

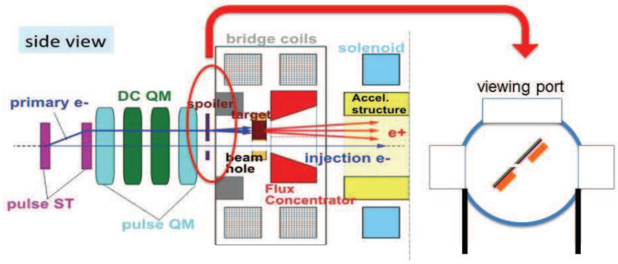

Figure 1: Schematic view of SuperKEKB positron source configuration and spoiler principle design.

SPOILER DESIGN AND ASSEMBLY

The spoiler has a double layers structure as we can see from the Fig.1, because it can be used not only as a scatter plate but also a screen monitor. In fact, the first layer is a screen and the second layer is a scatter plate. It is 45 degree tilted for the purpose of reflecting the beam image by screen through the view port. The screen and scatter plate is made of AF995R (Al_2O_3+CrO_3) and pure aluminum respectively. The properties of both of the materials have been listed in table1. Although we only expect a small amount of energy deposition in the spoiler and the screen, for the safety reasons, water cooling system is applied while a thermocouple is installed to monitor the temperature. The assembled spoiler has been implemented to the linac beam line as shown in Pic.2

Table 1: positron yield

Properties	Unit	Aluminum	AF995R
Density	g/cm^3	2.7	3.98
Melting Point	K	993.5	2000
Thermal Cond.	$W/m/K$	237	250
Specific heat	$J/g/C$	0.9	1.09
Radiation Length	mm	89	70.4

Due to the restriction of the beam line layout, there are few places where the spoiler could be installed. The cho-

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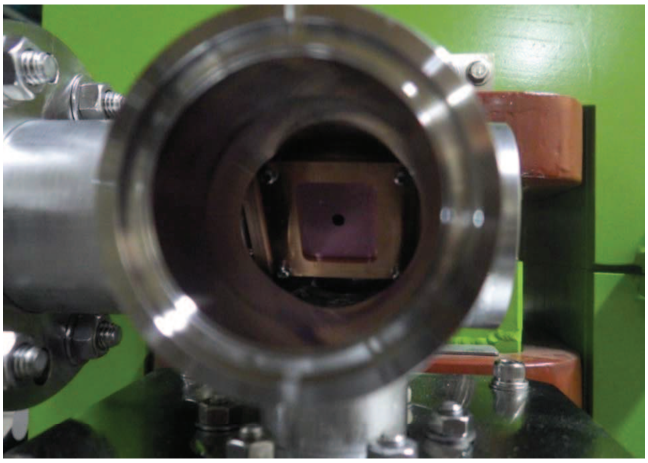

Figure 2: Beam spoiler has been installed in the linac beam line. The hole aperture is 3 mm.

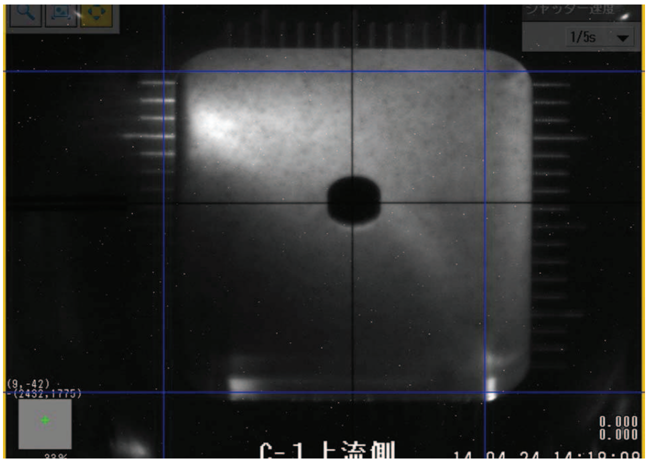

Figure 3: Telescope image of the spoiler alignment.

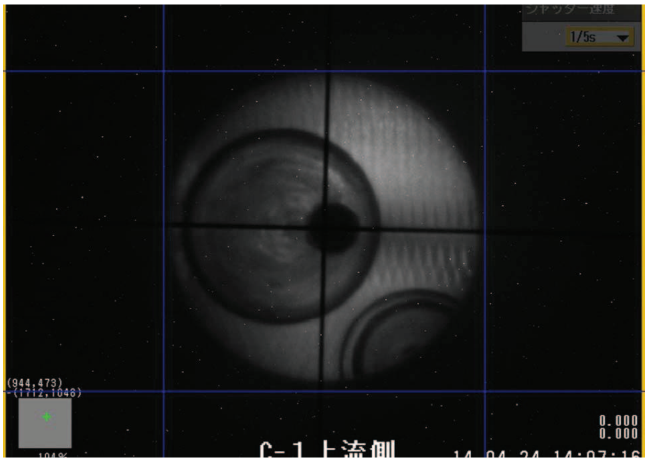

Figure 4: Telescope image of the target system alignment.

sen position locates 3 m upstream of the positron target. In fact, 3 m is a good drift distance requiring relatively thinner spoiler, which could see less positron yield reduction. And also the 3 m position is close to the pulsed quadruple, which is secure from the mis-focusd electron beam. As we have discussed in previous section that a spot size of 0.7 mm is desirable. Therefore, a combination of 0.1 mm screen and 0.2 mm scatter plate should sufficiently scatter the electron beam. After drifting 3 m to downstream target, the aiming spot size could be achieved.

SPOILER AND TARGET ALIGNMENT

For a pulse-to-pulse switching system, the pulse for generating positrons will be steered off axis and scattered by spoiler. And the injection pulse needs to pass through the spoiler and target. Therefore, the spoiler has a passage hole of 3 mm in diameter in the center, and the target hole is 2 mm in diameter. Alignment of those two passage holes need to be defined. The spoiler hole and the target hole need to be well aligned because the injection electron beam has to pass through without any interference. The desirable level of alignment is about ± 0.1 *mm* in both horizontal and vertical direction. After installing the spoiler and the target into the linac beam line, an alignment measurement has been done. A telescope was placed at the upstream of the pulsed quadruple. It was perfectly aligned with the beam line. The CCD camera attaching to the telescope could help us to get the image. The measurement results showed spoiler was about 1.5 mm and 0.1 mm offset to the west and up respectively. The vertical misalignment was fine. But in the horizontal direction, certain action for correction was necessary. Therefore, a well-defined 0.2 mm shim was inserted to correct the spoiler to the east direction. The Pic.3 shows the spoiler had a misalignment of 0.05 mm after the correction.

Other than the spoiler alignment, we have also done the alignment measurement for the target. As we can see from the Pic.4, the positron target system had an offset to east about 0.3 mm, and vertically down about 0.05 mm. We cannot correct the offset because the reference alignment track is on the west side, which means only the west offset could be corrected. To sum it up, both of spoiler and the target system had a precise alignment in the vertical direction. Whereas in the horizontal direction, the spoiler and target system had a 0.15 mm misalignment to west and 0.3 mm misalignment to east respectively. The spoiler offset has been reduced to 0.05 mm to east by inserting a shim. Hence, the target system is 0.25 mm offset with respect to the spoiler center. And the electron injection needs to be carefully adjusted.

SUPERKEKB POSITRON BEAM COMMISSIONING

SuperKEKB positron beam has started to commission since 2014. The detailed positron source construction situation could be found in paper [5]. The beam spoiler as an important protection component has been installed 3 m upstream of the target. The electron beam charge in this stage is about 0.8 nC. After passing the J_arc, the charge for positron generation is about 0.4 nC. The experiment

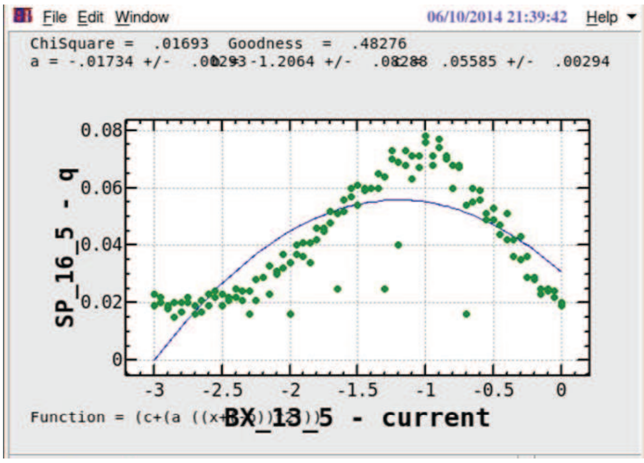

Figure 5: BMP(SP_16_5) measurement of positron charge as a function of the steering (BX_13_5) current. Primary electron beam passed through the spoiler center hole.

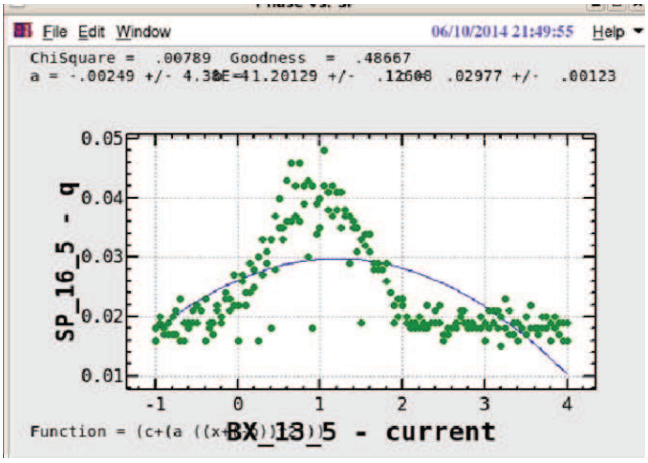

Figure 6: BMP(SP_16_5) measurement of positron charge as a function of the steering (BX_13_5) current. Primary electron beam was scattered by the beam spoiler.

has been carried out to test the influences of the spoiler to positron yield.

At first, we would like to let the primary electron beam pass the spoiler hole before being steered (BX_13_5) to strike on the target. The generated secondary particles will be captured and accelerated. In the chicane section, secondary electrons would be separated and dumped. Then the positron beam charge would be measured by the downstream BPM (SP_16_5). The result is shown in Fig.5.

As we can see from Fig.5, the positron charge is position dependent. With a 0.4 nC primary electron beam, without being scattered by spoiler, the maximum positron charge was about 0.08 nC. The detailed positron yield and position dependent could be found in paper [6]. In order to investigate the beam spoiler impact, we then used the spoiler to scatter the primary electron beam, and followed the same procedure as the previous test to evaluate the positron beam charge. The BPM measurement result is shown in Fig.6.

The Fig.6 shows the same position dependent as the previous measurement. However, the peak value of the positron charge is reduced from 0.08 nC to 0.045 nC. The reduction is mainly because of introducing the beam spoiler. The spoiler's design value is to enlarge a pin point electron beam to a RMS radius of 0.7 mm. At this stage of operation, the electron beam is not well optimized, which means the spot size is fairly large. After scattering, it could strike out of the target area. Then combine with the effect of the steering angle and other contribution, the positron charge degradation is reasonable. Further beam test has been planned, and will take place later this year.

CONCLUSIONS

In this paper we have reported the beam spoiler assembly and beam test. It has been successfully. The spoiler is installed in the linac, locating 3 m upstream of the target. The water cooling system is applied to make sure the spoiler will not be damaged by the high intensity electron beam. At the same time, the thermocouple would help us to monitor the temperature changes. Before firing the electron beam, the spoiler and the target misalignment has also been measured. After correction, the spoiler would only have a 0.05 mm offset from beam line center. Whereas the target system is 0.3 mm offset with respect to the beam line center. Therefore, the electron injection needs to be carefully adjusted. After all the preparations, we had a 0.4 nC primary electron beam for spoiler investigation. For the purpose of comparison, we firstly let the electron beam pass the hole to strike the target. And then repeat the same measurement but make the electron beam go though the spoiler before hitting the target. The results indicate that the spoiler could enlarge the beam spot size, which has caused a positron charge reduction from 0.08 nC to 0.045 nC. Considering this is the early stage of the SuperKEKB electron and positron commissioning, such result is expected. Further spoiler investigation and positron beam study will be carried out later this year.

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