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THE FIRST BEAM EXPERIMENT RESULT OF THE PROTYPE OF WIRE SCANNER FOR SHINE *

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Abstract

As a kind of quasi-non-destructive beam size monitoring, SHINE will employ dozens of wire scanners. The preliminary study is confronted with motion control difficulty. To reduce the ultrahigh coordinate about wire movement with beam loss data acquisition, a new method has been proposed in the SXFEL test platform. The strategy is utilizing the beam jitter, which is of the same magnitude with the beam size. Combine with the jitter of the beam position, we move tungsten wires in a few of different position to realize the measurement. This paper will present our experiment design as well as a furthermore plans about the prototyping design.

INTRODUCTION

As a quasi-non-destructive beam size and emittance measurement system, wire scanner is widely used in linear accelerators worldwide [1]. As a classic beam size measurement system, the measurement principle of wire scanner is very simple. It is assumed that the downstream secondary product flow is proportional to the intensity of the electron beam passing through the tungsten wire [2]. The secondary products mainly include high-energy electrons, gamma rays and secondary currents generated on tungsten wires. Therefore, the signal detected by the downstream photomultiplier is positive correlation with the beam intensity, and the size of the beam can be measured by accurately measuring the distance of the tungsten wire movement. In addition to the application of the wire scanner for accurate beam size measurement, one or several sets of such detectors can also be used to complete offline or online beam emittance measurement and energy dispersion measurement.

In this article, we discuss the hardware and software structure of the SHINE wire scanner prototype and the first beam experiment results.

IDEA

The initial setting is to use wire scanner to scan the beam transversal section at a uniform speed [3]. Take advantage of the high repetition frequency of the SHINE, the position of the wire and the beam interaction can be obtained. Combining the beam loss data, we can calculate the beam size using Gaussian fit.

Since the SHINE is still under construction, our wire scanner prototype is installed in the SXFEL facilty for testing at present. It is differ from the hard X-ray free electron laser facility with high repetition frequency(up to 1MHz), the current repetition frequency of the SXFEL facilty just 2 Hz. Under the circumstances, the fast scan method requires high precision for the timing system, also the movement speed requirement for linear motor uniform scanning is too low. After the first preliminary experiment, we acquired that the beam size of the SXFEL is in the magnitude of several hundred microns, and the jitter of the beam position is about the same order of magnitude. This will introduce a noticeable uncertainty of measurement using the fast scan mode. However, it provides a new idea for the SXFEL experiment adopt a static testing method. We can make use of the beam jitter, acquire a step-by-step scanning method in the SXFEL wire scanner prototype principal verification stage.

The basic idea is fixing the position of the wire target, changing the original wire scanning motion mode of the wire sweeping the beam to the beam sweeping wire. We can get the beam loss signal and beam position signal in different beam positions due to beam jitter. The step-by-step static testing is using the CBPM to acquire the accuracy position(position resolution up to 200nm). The data acquisition system using external clock and external trigger come from electronic chamber, which can guarantee the synchronization of the beam loss and the impact point.

SYSTEM SETUP

The wire scanner system is comprised of the mechanical execution structure and the beam loss detector in the tunnel, the upper computer and the data acquisition board outside the tunnel. Figure 1 is the installation photo in the tunnel. From nearest to farthest, CBPM is upstream the mechanical execution structure, the beam loss detector is installed downstream parallel to the vacuum pipe.

After the tensile test of 10 μm tungsten wire and 20 μm tungsten wire, we chose 20 μm tungsten wire as the test wire for the first version of the prototype. The tungsten wire is mounted on the customized fork connected to the linear motor, it was distributed in three directions testing the beam size in the horizontal direction, the vertical direction and the oblique 45 degrees(see Fig. 2).

We use the linear motor of LinMot to drive the wire target. The main motion modes of the motor are as follows:

- Step by step test: In this mode, the scanner will move to the user defined position for several test, after that, it will move to another position. The sample interval is defined by the beam jitter.

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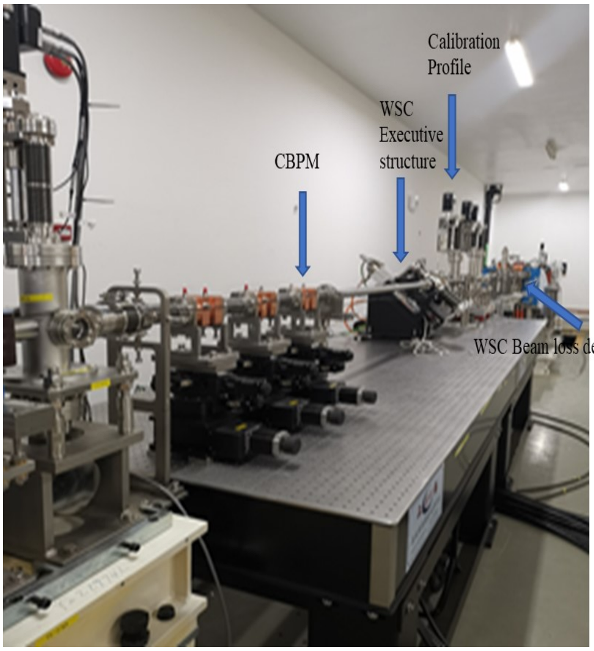

Figure 1: Installation photo in the tunnel.

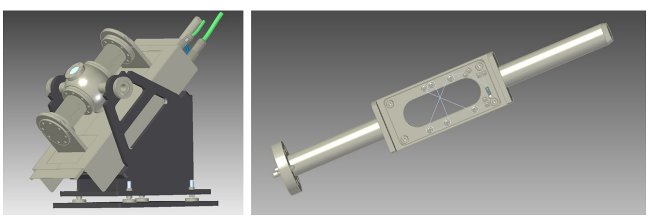

Figure 2: The Prototype Wire Scanner Executive Structure & the wire structure.

- Fast scan: This is intended to execute a motor pattern download in server, which defined the velocity, accelerated velocity and stroke.
- User scan: The operator independently adjusts the motor position according to the current position, the control panel has a variety of operation options, and the motor server controls the motor according to demand.

In order to better evaluate the mechanical execution structure and make a backup at the same time, we also installed the same 20 μm tungsten wire on the adjacent proflie calibration screen(see Fig. 3).

The following Fig. 4 is the wiring diagram of the wire scan prototype. We introduce the timing signal from the timing system as the trigger signal of the data acquisition board. At the same time, we use the frequency synthesizer multiplication timing signal as the clock signal. The four channels of the data acquisition board are collected respectively. Loss signal, two position signals of CBPM horizontal direction and vertical direction and CBPM reference cavity signal used for normalized charge.

Figure 5 is the linear drive module.The grey part is the linear motor, the green part is the package structure, it can provide mechanical alignment for linear motor installation.

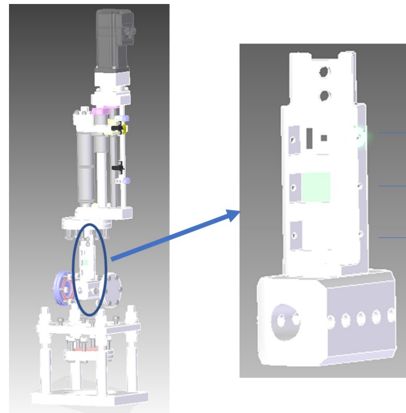

Figure 3: The Prototype Profile Structure & the screen formation.

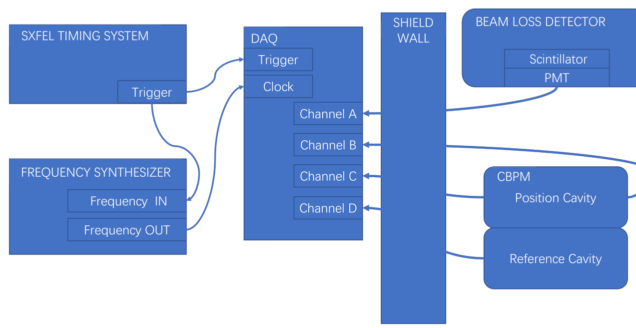

Figure 4: The diagram of the wiring connection.

The white part is the linear encoders, we choose the Heidenhain LIC411 which position resolution is 0.1 μm.

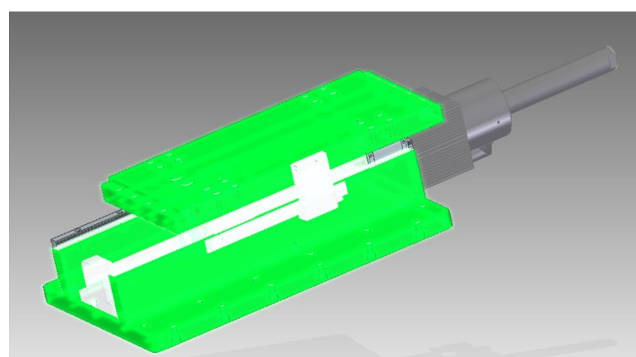

Figure 5: Linear drive module. The grey part is the linear motor, the green part is the package structure, and the white part is the linear encoders.

EXPERIMENT RUSULTS

After the software and hardware installation was completed, we carried out the beam current experiment in the SXFEL facility. First, with the YAG screen of the profile near the wire scanner, we verified that all three directions of the tungsten wire can interact with the beam, Figure 6 shows the images caught by the CCD camera when passing

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through the beam. The images illustrate the beam interation with the tungsten wire.

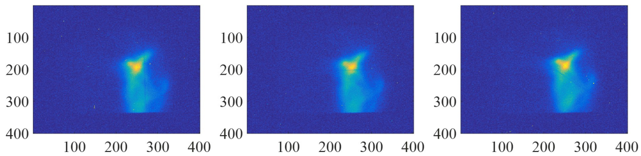

Figure 6: Three directions of tungsten wire and beam interaction diagram.

Use the data acquisition board to synchronously collect the beam position signal and the beam loss signal. The CBPM reference cavity signal can be used to normalize the charge amount of the position and beam loss signals. Figure 7 shows the signal received by the beam loss detector under the interaction between the wire and the beam, and the normal wireless state. The figure shows that the noise floor has a large peak, which is suspected that the beam interact with the remaining air molecules in the vacuum tube. More supplementary experiments will be arranged later.

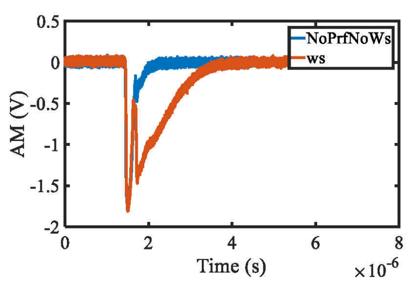

Figure 7: Beam loss signal.

In view of the complexity of the noise background, our system resolution is not ideal for the beam loss signal represented by the peak signal after deducting the noise floor. Although the overall trend of the data fits the Gaussian distribution(see Fig. 8). The calculated beam spot size is larger than the profile test result.

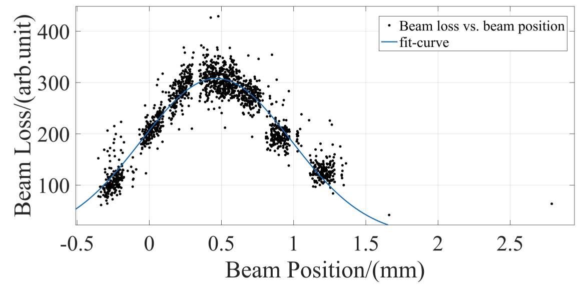

Figure 8: Beam loss vs beam position.

CONCLUSION

Wire scanner system are keeping update. In the next step, we will try to adjust the execution structure and the position of the beam loss detector, adjust the detector installation position and other methods to improve the beam loss signal reception efficiency and improve the system resolution. At the same time, to ensure that the mechanical execution structure can operate stably in the free electron laser facility with high repetition frequency, we will conduct some destructive experiments to verify it in the later stage.

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