THE WIRE SCANNER AT BEPCII

Y. F. Sui, J. S. Cao
Institute of High Energy Physics, Beijing 100049, China

Abstract

To monitor the beam profile in injector of BEPCII which is the upgrade project of Beijing Electron Positron Collider (BEPC). Several beam diagnostic and monitoring instruments are used. Wire scanner as a new diagnostic instrument was designed and manufactured to measure the beam profile at the end of linac in 2007.During the shutdown period of BEPCII we had installed the system at the end of linac. After that we had done beam test for several times. This paper describes the whole system of wire scanner and the result of several times beam test. Recent progresses and some discussion of the beam test result will also be present..

INTRODUCTION

The BEPCII is a double-ring collider with high beam current and high luminosity. It consists of three parts: an injector linac, beam transport lines and storage rings. The energy of the linac is 1.89GeV with a repetition rate of 50Hz [1]. In order to monitor the beam profile at the end of the linac, a wire scanner equipment has been developed. The system has a gold plated wire with 100-micron diameter, and is moved transversely across the beam. The gamma-ray photons and secondary-electrons, which are caused by the interaction between beam and wire, are observed by a photomultiplier detector with a 20mm×30mm×5mm scintillator on head [2]. This beam measuring method is based on two assumptions: i) the beam in the linac is stable enough over many shots, ii) the flux of the secondary products, which currently includes scattered high energy electrons, gamma-ray photons, and the secondary-electron current, is proportional to the intensity of the electron beam passing through the wire[3]. A prototype wire scanner has been fabricated and installed at the end of the linac in autumn 2007.

DRIVE SYSTEM

The drawing of the BEPCII wire scanner is shown in Fig. 1. Three gold plated tungsten wires with a diameter of 100 microns are mounted to the wire scanner fork to measure the beam profile in three different planes. Each of the three wires meets the others at an angle of 45 degrees. The wires go across the beam horizontally, vertically and in the 45-degree direction by moving the wire fork backward and forward. So we can call them H-, V- and U-wire[4]. The three wires are offset from each other so that no more than one wire at a time is within the beam centre. A special collet is used to hold the wires in place with a small tension to accommodate thermal expansion and contraction. The linear slide has a stroke of 125mm. The step motor is selected to provide a 2.1N·m torque, which is required to overcome the vacuum force and move the wire card into and out of the beam. A potentiometer (linearity ±0.075%) is also needed to measure the position of the wire card and is installed on the body of the system. The flange, bellows, and wire card assembly are required to resist the high temperature of baking. The actuator has two limit switches at each end of the motion.

We have simulated the temperature change of the wire using ANSYS®. The highest temperature of the wire is 2700K which is less than the melting temperature of tungsten. Also, given the result of the static structural force, we can confirm that the wire can survive in the electron beam with a repetition rate of 50Hz and a peak current of 500mA [5].

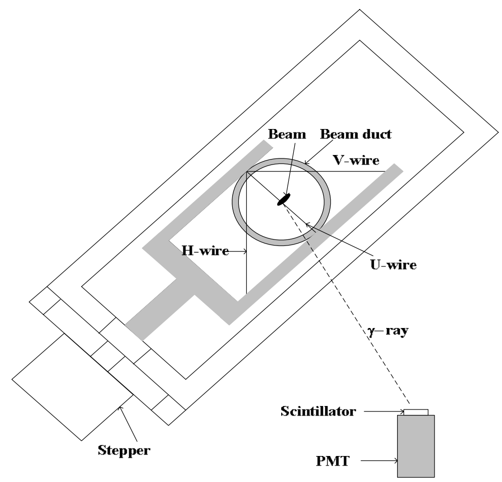

Figure 1: Schematic drawing of the wire scanner.

The accuracy of the beam size measurement is depending on the accuracy of the actuator. An experiment has been performed to measure the linearity of the actuator after the wire scanner was installed at the end of the linac. The actuator was moved step-by-step of equal-length by issuing a certain number of pulses to the stepper. After each moving we measured the position of the actuator with vernier calipers. The plot of the measured actuator position vs. the number of steps issued to the stepper is shown in Fig. 2 [6]. The result shows that the linearity error of the actuator is 0.16% which is much better than the design accuracy of 5%.

ELECTRONICS

Front-end Circuit

The photomultiplier tube (PMT) detector is located at the downstream of the wire scanner and a 1000 DC voltage is applied. When the α,γ particles hit the detector, a pulse signal will be produced. The area of the pulse signal is proportional to the quantity of particles hitting the detector. The front-end circuit uses the pulse signal from the PMT detector as the original signal. The pulse signal is transferred from the detector to the fast gated integrator and boxcar averager through a 30m coaxial-cable. The integrator is driven by the time signal which is synchronized with the time signal for the electron gun. The pulse signal is integrated and averaged in the integrator and Boxcar averager module. The output signal is a DC voltage signal and sent into the ADC. The busy out signal of this module is used to trigger the ADC. Fig.3 shows the Front-end Circuit of the wire scanner system.

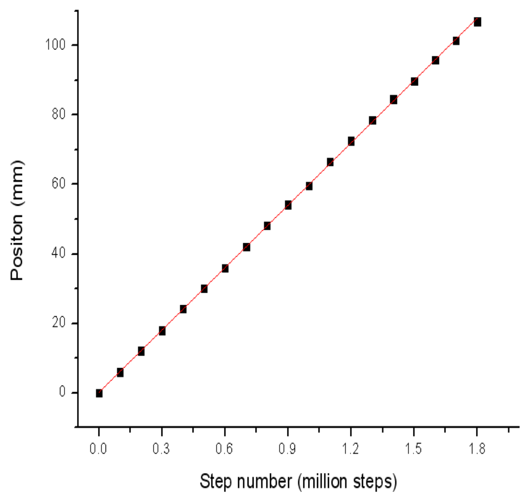

Figure 2: Position of actuator vs. step numbers.

Data Acquisition System

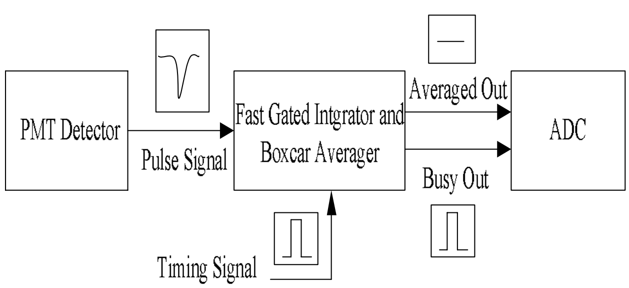

Figure 3: The Front-end Circuit of wire scanner system.

The electronics of data acquisition system includes a National Instrument(NI) PXI chassis with a controller, two signal processors and a motion controller, a NIM modular chassis with a high voltage power supply and a gated integrator and a motor driver. The PXI chassis have several functions: 1) Acquiring the signal from the gated integrator output and photometer, and digitizing them; 2) Controlling the motor moving forward and backward motion of the motor via the motion control; 3) Applying the voltage to the power supply card which determines the high voltage applied to the PMT. The NIM crate functions: 1) Applying high voltage to the PMT from the high voltage power supply card; 2) Integrating the signal from the PMT with the beam timing signal as a gate. Fig. 4 shows a block diagram of the system. The motion controller drives the motor with a step resolution of 0.5μ m. At first the position of the wire is monitored by the potentiometer, but we found that the resolution can't meet our demands. So we turned to count the pulse issued to the stepper motor. The potentiometer is used to double-check whether the actuator is operating properly. The driving unit is controlled by one of a four-channel NI PXI-7344 motion control card sitting in a PXI crate. The crate is controlled by the PXI-8195 which supports NI LABVIEW. The programme controlling the motion of the actuator is completed in the NI LABVIEW graphical programming environment. Another application is developed to measure the signal from the gated integrator. A share memory, one of the most important components, also runs in this environment [7]. The motion control PC is controlled via Ethernet by the EPICS control system.

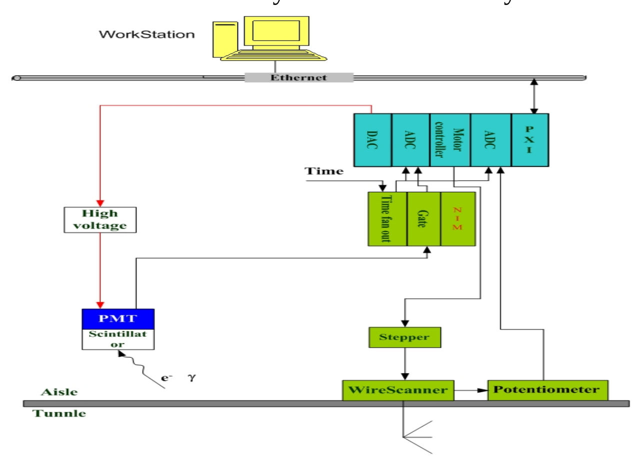

Figure 4: The schematic diagram of wire scanner electronics.

THE MEASUREMENT RESULTS AND ANALYSIS

After the wire scanner was installed into the BEPCII transport line in the autumn of 2007, we had done experiments for several times. In the following parts of this paper, the results of experiments will be show and some necessary discussion will also be made.

At the beginning of wire scanner operation, the signal-to-noise ratio is small for the measurement of the electron beam profile. Nothing can be detected from the downstream of the detector when we try to measure the positron beam profile. We think the possible reason is the strong background at the end of the linac. Because the signal to noise ratio is easily affected by even a very small beam loss in upstream of the monitor. [8] To reduce the background noise, we covered the PMT closely with some plumbeous block. Especially we placed other Pb blocks on the side which faces to the upstream of the beam.

After shielding the detector and tuning the Q-magnet, we got a perfect beam profile in Fig.5. Fig.6 shows that the beam profile fit the Gaussian shape very well. From the fitting result, we know the rms beam size is σ_x/σ_y=1.325/1.276mm, which is close to the theoretic value 1.23/1.23 mm. we can see that the measured beam profile is little different from the design value. In spite of this, many studies still need to be done to reduce the errors and find their origin.

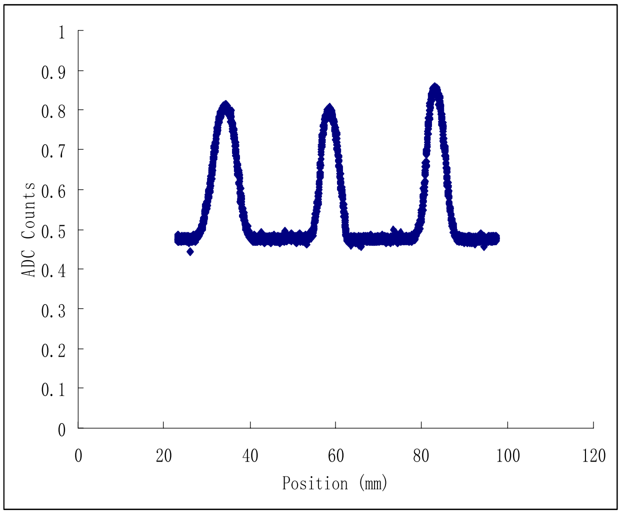

Figure 5: The measurement result of beam profile wire scanner.

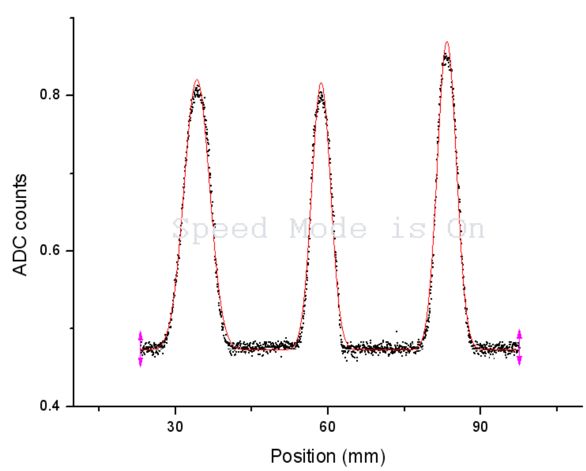

Figure 6: Display of fitted beam profile (raw data point, fitted data line).

We develop a programme with the SADScript to control the system remotely. The programme can send command to the control the motion of the device, acquire the data from local controller, fit the data with the Gaussian shape and plot the result in the interface. Fig.7 is a measurement results in this programme.

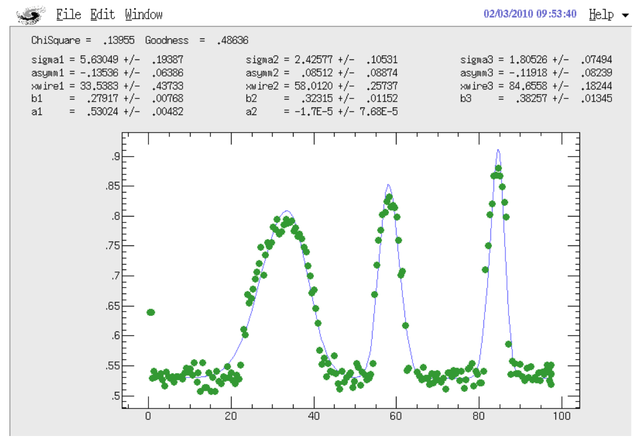

Figure 7: the fitted beam profile in SAD Programme (raw data point, fitted data line).

CONCLUSION

A wire scanner system based on LABVIEW and shared memory has been built to measure the beam profile at the end of the linac. The software was developed under SAD and EPICS environment. The preliminary measurements of the transverse size show that the system performed well. We are planning to measure the emittance of the beam using three wire scanners.

We acknowledge H.fukuma and N.iida of KEK for their useful advices and fruitful discussions. We thank Xu Gang and Lei Ge for their patient help in SAD programming. Thanks are also devoted to the members of the beam instrumentation group for their useful discussion and cooperation.

REFERENCES

[1] BEPCII primary design report of the linac accelerator (IHEP-BEPCII-SB-03-2）
[2] N. Iida, T. Suwada, Y. Funakoshi et al. In Proceedings of APAC, Japan,1998, 546-548
[3] J.L. Bailey, B.X. Yang, T.W. Buffington. In Proceedings of PAC, USA, 2005, 3667-3669
[4] Y. FUNAKOSHI, N.IIDA et al, In Proceedings of APAC, Japan, 1998, 537-539
[5] SUI.Yan-Feng, MA.Hui-Zhou et al. Chinese Physics C ,2008, 32(5):397
[6] SUI.YF, CAO JS, MA L. In Proceedings of EPAC, Italy 2008,1293-1295
[7] D. Thompson, W. Blokland. In Proceedings of ICALEPCS, Korea, 2003, 275-277
[8] Y. FUNAKOSHI, N.IIDA et al, Proceedings of APAC, Japan, 1998, 537-539