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BEPCⅡ wire scanner system*

SUI Yan-Feng(随艳峰)[1,2;1)] WANG Lin(汪林)[1] ZHAO Ying(赵颖)[1]
YUE Jun-Hui(岳军会)[1] LI Xiao-Ping(李小平)[1,2] CAO Jian-She(曹建社)[1] MA Li(马力)[1]

[1] Institute of High Energy Physics, CAS, Beijing 100049, China
[2] Graduate University of Chinese Academy of Sciences, Beijing 100049, China

Abstract To monitor the beam profile at the end of the linac non-destructively, a wire scanner as a new diagnostic instrument was designed, manufactured and installed in 2007. Since then, several measurements have been carried out using this device. This paper describes the whole system of the wire scanner and the testing results.

Key words BEPCⅡ，beam instrument, beam profile, wire-scanner

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1 Introduction

The BEPCⅡ (the upgrade project of Beijing Electron Positron Collider) 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 1.89 GeV with a repetition rate of 50 Hz [1]. In order to monitor the beam profile at the end of the linac, a wire scanner 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 the beam and the wire, are observed via a photomultiplier detector with a 20 mm×30 mm×5 mm scintillator on the head [2]. This beam measuring method is based on two assumptions: i) the beam in the linac is stable enough over many shots, and ii) the flux of the secondary products, which currently include 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 was fabricated and installed at the end of the linac in autumn 2007.

2 Drive system

A 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. Thus we can call them the H-, V- and U-wires [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

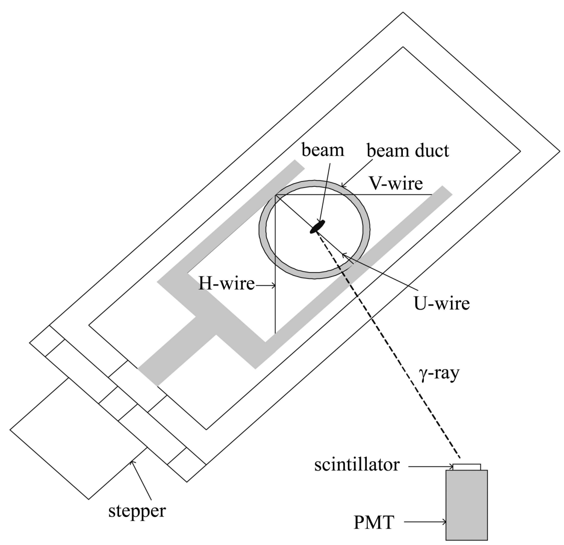

Fig. 1. Schematic drawing of the wire scanner.

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* Partly supported by JSPS & Core University Collaboration Foundation
1) E-mail: syf@ihep.ac.cn

small amount of tension to accommodate thermal expansion and contraction. The linear slide has a stroke of 125 mm. The step motor is selected to provide a 2.1 N·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 2700 K 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 50 Hz and a peak current of 500 mA [5].

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% .

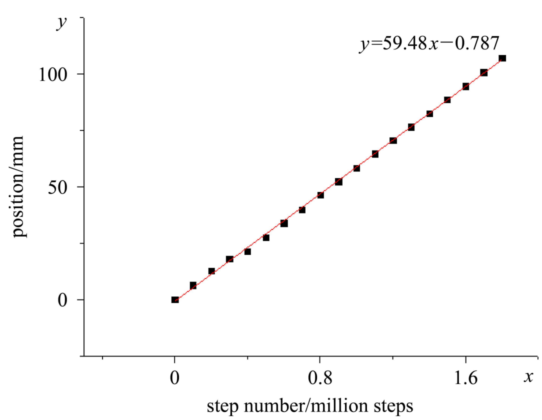

Fig. 2. Position of actuator vs. step numbers.

3 Electronics

3.1 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 30 m 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 is 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.

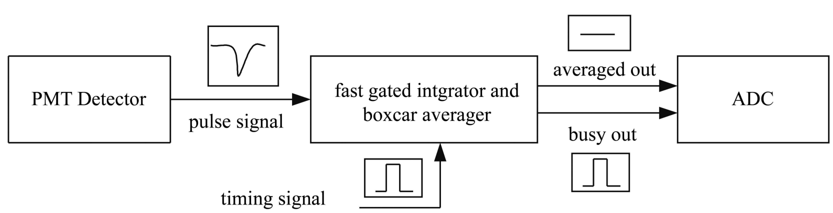

Fig. 3. The front-end circuit of the wire scanner system.

3.2 Data acquisition system

The electronics of the 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 has several functions: 1) acquiring the signals 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 and 3) applying the voltage to the power supply card, which determines the high voltage applied to the PMT. The NIM crate functions are 1) applying high voltage to the PMT from the high voltage power supply card and 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 0.5 μm. 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.

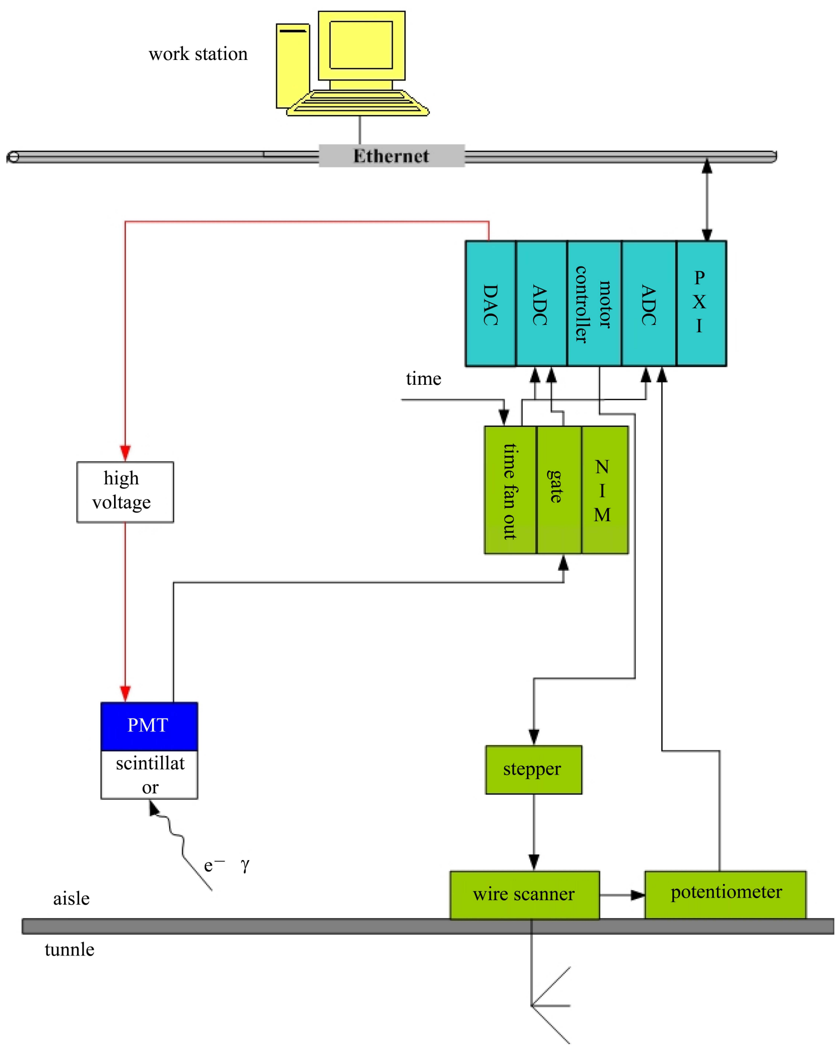

Fig. 4. Schematic diagram of the wire scanner electronics.

4 Measurement results and analysis

Several experiments were done in autumn 2007. At the first stage of the measurement, the signal-to-noise ratio is small for the measurement of the electron beam profile due to the beam loss upstream of the monitor [4]. To reduce the background noise, we covered the PMT closely with some plumbeous blocks. In particular, we placed other Pb blocks on the side which faces the upstream of the beam.

After shielding the PMT, the wire scanner system worked well. Fig. 5 shows the result of the positron

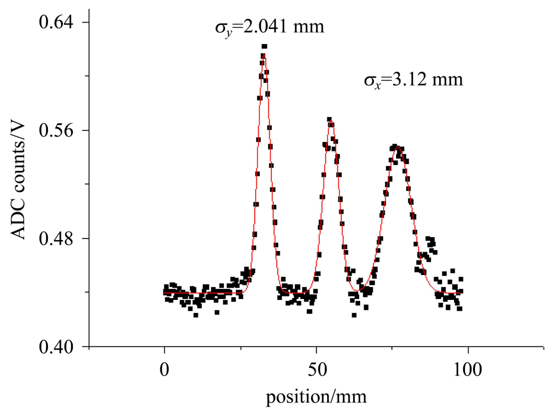

Fig. 5. Display of fitted positron beam profile (raw data points, fitted data line).

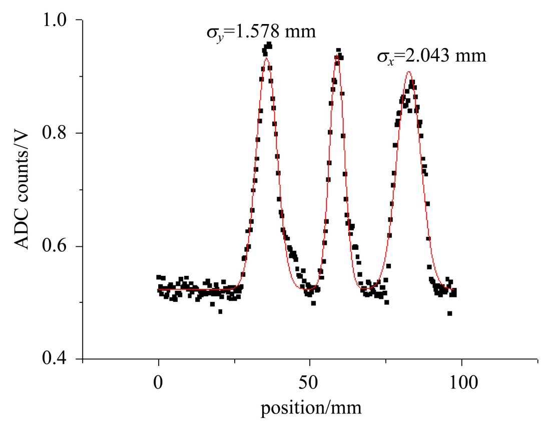

Fig. 6. Display of fitted electron beam profile (raw data points, fitted data line).

beam profile, fitting a Gaussian shape. Fig. 6 shows the fitted result of the electron beam profile. From the fitting result, the rms beam size of the positrons is σ_x/σ_y=2.041/3.12 mm, which is close to the theoretic value of 2.19/3.098 mm. The rms beam size of the electrons is σ_x/σ_y=2.043/1.578 mm and its theoretic value is 2.078/1.624 mm. The relative error between measured results and the theoretical values is near 5%, which is the design value of the wire system. In spite of this, many studies still need to be done to reduce the errors and find their origin.

5 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 the 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.

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