KB Focus Mirror Mechanism Control System Design and Application

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Abstract

The Shanghai Synchrotron Radiation Facility (SSRF) has developed its own white light KB focus mirror, which consists of a bending and adjustment mechanism, the movement of which is achieved by a piezoelectric motor. The control system is based on the joint development of EPICS and LabVIEW to realise the precision adjustment of multiple axes and multiple motors, where the underlying control of the equipment is realised with EPICS and the logic control and human-machine interaction interface is developed based on LabVIEW. The integration of the control system into the x-ray test line enables the focusing of micron-level white light beams and forms a complete experimental function, including motion control, detector data acquisition and light intensity detection, to meet the requirements for the detection of white light microbeam Laue diffraction from metallic materials.

Keywords

LabVIEW; KB Mirror; Stepper Motors; Piezoelectric Motors.

1. Introduction

As an advanced material characterisation technique, the synchrotron micro-beam white light Lauer method offers both micron/sub-micron spatial resolution and centimetre-level specimen characterisation, and in particular its excellent ability to rapidly detect crystal orientation and lattice stress/strain, showing unique and important potential for application in materials, physics and chemistry research[1]. The establishment of the synchrotron microbeam white light Laue method first requires micron-level white light focusing of the synchrotron beam, which is currently usually achieved by secondary focusing of the beam line's focused spot using a KB focusing mirror. As an important optical element, the KB focusing mirror needs to strictly meet the focusing conditions in terms of bending radius, face shape and spatial attitude in order to focus the beam to the micron level. Therefore, the motion accuracy of its bending and adjustment mechanism is extremely demanding, and the motion control of the KB focusing system has to be linked with the optical elements of the beamline for focusing optimisation. Data interaction with the control system of the beamline.

LabVIEW is widely used as general-purpose commercial control software for a variety of motor and detector applications, and also allows data interaction with EPICS used in beamlines via its protocol. Stepper motors are now widely used in a variety of applications due to their simple construction, easy control methods and the possibility of precise displacement positioning. In the field of optics to achieve nanoscale motion of KB mirrors, stepper motors alone cannot achieve the resolution required for experiments and require coordinated control of piezo motors and stepper motors[2]. The designed KB mirror focusing system is a multi-axis motion platform based on LabVIEW for remote control of stepper motors. The motion platform realises three-dimensional attitude adjustment in angular, horizontal and vertical directions, and this motion process mainly realises coarse adjustment of

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position. The LabVIEW program calls the EPICS program of the experimental line station to make the bending mechanism bend the KB mirror to achieve the micrometer focus of the KB mirror, so the control process requires the joint movement of several control devices to achieve the experimental purpose. In this paper, LabVIEW is used to implement the motion control of the white light KB focusing mirror system, and the intermodulation of the focusing light plate is achieved by calling the EPICS super annular mirror call via TCP/IP protocol. The results of the commissioning of the KB Focusing Mirror system on the radiographic test line show that it meets the requirements of the actual citation.

2. KB Focus Mirror

2.1 KB focus mirror construction

The KB focusing mirror system consists of two flat mirrors, modulated into ellipsoidal mirrors using a bending mechanism to focus the beam horizontally and vertically, respectively. The bending and adjustment mechanism is shown in Figure 1.

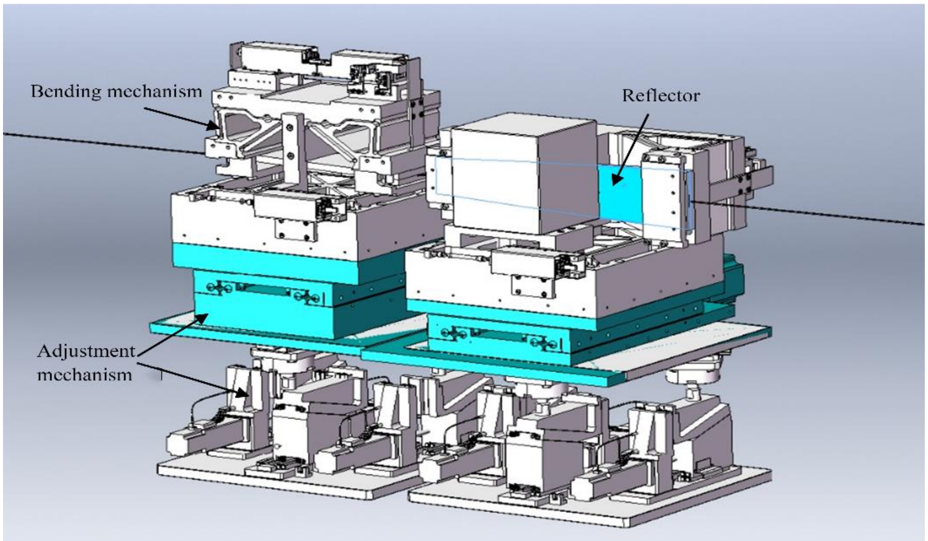

Fig. 1 KB focusing lens structure diagram

2.1.1 Bending mechanism

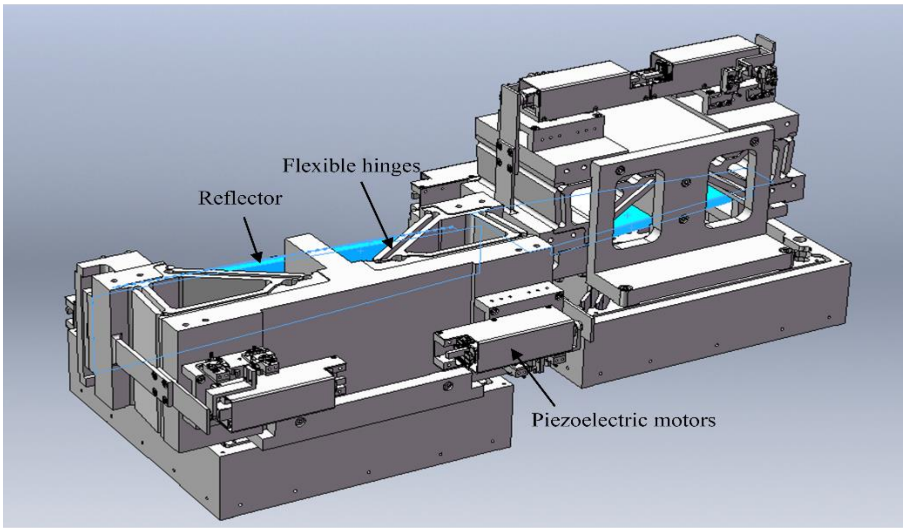

Fig. 2 Bending mechanism structure diagram

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The bending of the reflector is achieved by piezoelectric motors driving a flexible hinge, as shown in the diagram. Two motors are located on either side of the flexible hinge and can drive the movement of the flexible hinge separately. In order to increase structural strength and stability, flexible hinges are used to achieve movement in the throw angle of the horizontal focusing mirror and the swing angle of the vertical focusing mirror. The piezoelectric motor is manufactured by suna and its parameters are shown in the table below.

Table 1. Piezo motor parameter table

Motor	Value/nm	Resolution/nm
Rotation vertical bender	2000~-2000	1000
Vertical bender aix1	5000~-1000	1000
Vertical bender aix2	4800~-1000	1000
Rotation horizontal bender	2000~-2000	1000
Horizontal bender aix1	4100~-1000	1000
Horizontal bender aix2	3700~-1000	1000

2.1.2 Movement adjustment mechanism

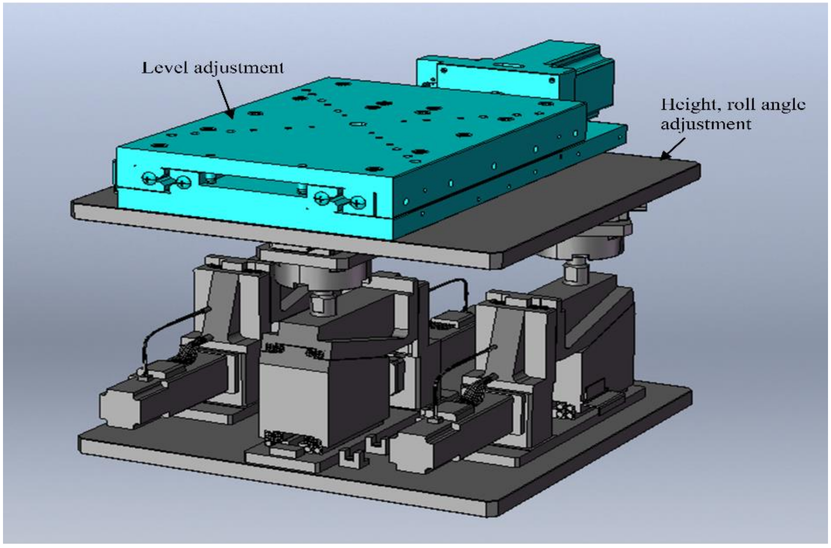

Fig. 3 Structure diagram of motion adjustment mechanism

The adjustment of the reflector is mainly made by the combination of horizontal and three-point support mechanism. The adjustment mechanism for horizontal focus is shown in the figure, and the three-point support adjustment mechanism can also move three motors respectively to achieve the adjustment of the roll angle of the reflector. The XA25's (KOHZU) are used horizontally, which can move ±25mm under resolution conditions, and the heps are used vertically and equipped with a speed reducer to meet the 0.2″ requirement.

Table 2. Reflector adjustment parameters table

Motor	Value	Resolution
X	10mm~-10mm	0.1mm
Z	10mm	1μm
Yaw(Horizontal)	1deg~-1deg	0.5deg
Roll (Horizontal)	2deg~-2deg	0.1deg
Pitch(Vertical)	1deg~-1deg	0.5deg
Roll (Vertical)	2deg~-2deg	0.1deg

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3. Control system design

The system consists of three main components: the Shanghai Light Source beamline equipment experimental station equipment, a 3D adjustment platform for adjusting the motion attitude and a press-bend mechanism device for controlling the stretching motion of the KB mirror. Firstly, by calling the EPICS program at the experiment station, the beamline device is moved to the appropriate position and the white light required for the experiment appears. The upper computer through the LabVIEW program makes the controller send out pulse signals to the stepper motor driver, the stepper motor driver converts the electrical pulse signals into angular displacement signals to make the stepper motor move at a fixed angle according to the set direction, the number of pulses can be controlled to control the angular displacement of the stepper motor movement, and the frequency of the pulses can also be controlled to control the speed and The frequency of the pulses can also be controlled to control the speed and acceleration of the stepper motor, thus achieving speed regulation and precise displacement control. The displacement movement of the stepper motor is used to adjust the motion attitude of the multi-axis motion stage so that the synchrotron light passes through the KB focusing mirror, and finally the EPICS program of the piezo motor is called to make the piezo motor do nanometer displacement movement, and the movement of the piezo motor makes the KB focusing mirror bending mechanism move, which in turn makes the reflector do stretching movement to achieve the purpose of the experiment.

3.1 Control objects

Due to the simplicity of stepper motor control and the mature technology in industrial control, the three-dimensional adjustment platform of the KB focus mirror system uses stepper motors. The motion control of the stepper motor requires a controller and a driver, which generates pulses and can drive the movement of the stepper motor after the driver converts the pulse signal into an angular displacement signal[3]. For integration management and ease of experimentation for researchers, the controller and drive are integrated in a single cabinet, as shown in Figure 4.

Fig. 4 Controller and drive integrated cabinet

The controller provides a stable pulse output with a wide range of pulses and a high degree of adjustability. For different pulse frequencies can control the controller output different types of pulse,

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and thus control the stepper motor more stable operation, to a certain extent effectively avoid the stepper motor in the process of movement of mechanical vibration phenomenon. The drive current of the driver ranges from 0.30A to 1.35A and can be subdivided up to 4000. The holding current is about 40% of the drive current and the internal design of the circuit contains functions such as limit switch signal processing and hardware protection.

3.2 Human Machine Interface

Figure 5 shows the control interface of this control system. The control interface of this system is written in LabVIEW language, which can achieve the horizontal, vertical and angular adjustment of the 3D adjustment platform through multi-axis linkage.

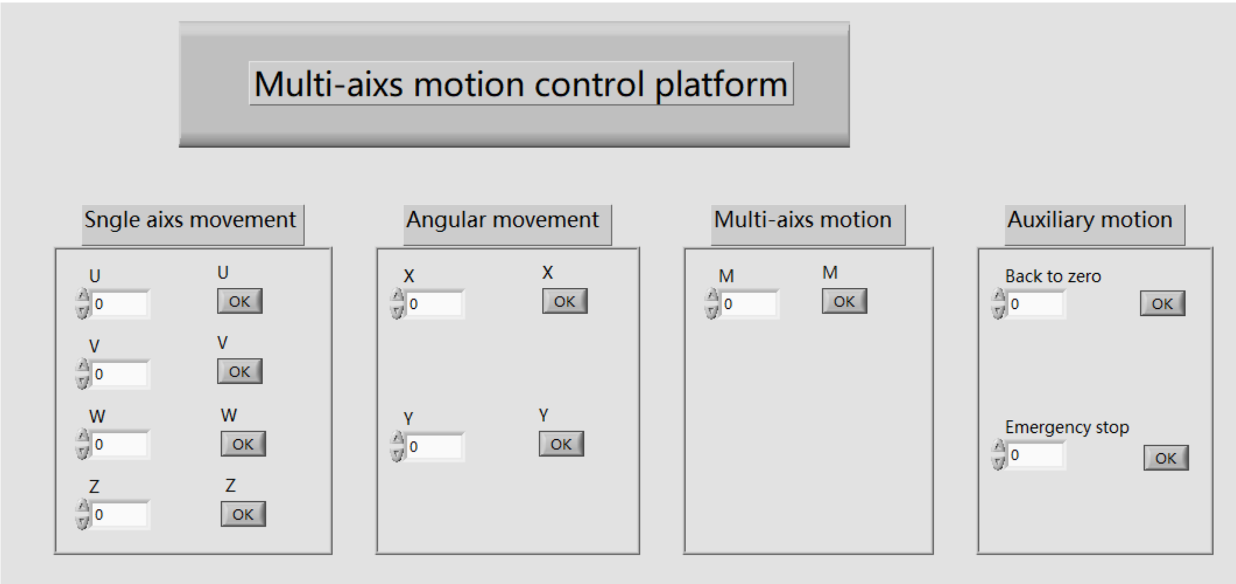

Fig. 5 LabView control interface

Figure 6 shows the control interface of the KB mirror bending mechanism. The LabVIEW program gets different PV values for each variable in the EPICS program based on the Linux system through Calab, and the LabVIEW program calls each PV value to call the EPICS program under the Linux system to make the piezoelectric motor bend and stretch the KB mirror.

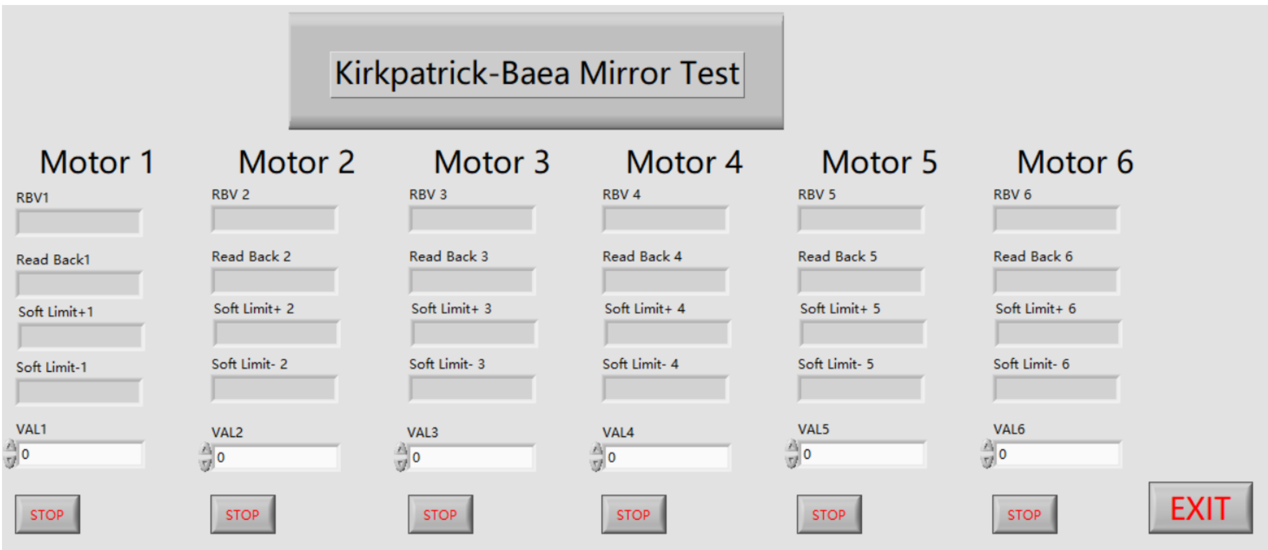

Fig. 6 KB mirror bending mechanism control interface

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4. Online test experiment results

To verify the performance of this control system, the Shanghai Light Source X-Ray Optical Test Line Station was tested online and the results are shown in Figure 7. To verify the stability and repeatability of the system, light spots with the same size were obtained after six experimental results; therefore, this data proves that the system has good stability and repeatability[4].

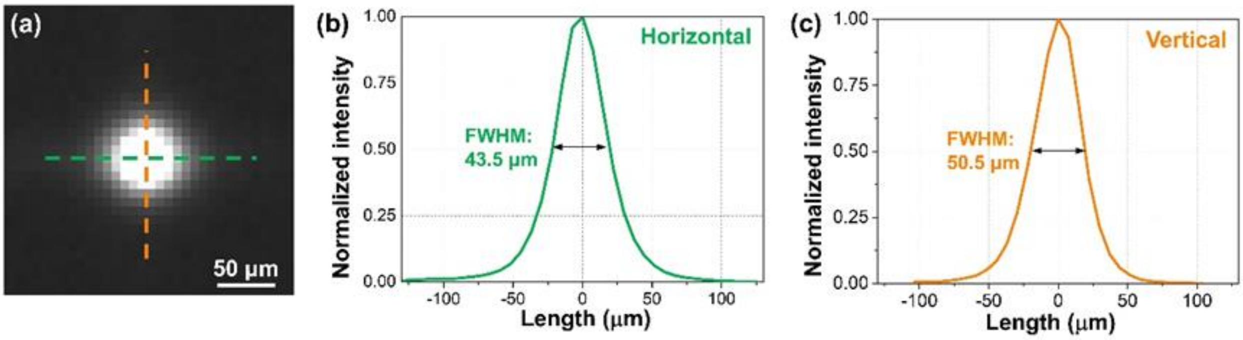

Fig. 7 X optical online test data

5. Conclusion

LabVIEW software is applied to call the EPICS program under Linux system under TCP/IP communication protocol to realize the multi-axis linkage of stepper motor and the program call of piezoelectric motor, which improves the integration of the system, reduces the cost of the control system and solves the problem of non-interconnection of control systems under different operating systems. The user interface is simple and easy to operate, which greatly improves the efficiency of the experiment. The system has been verified by several experiments to have good stability and performance, and has important application significance for the design of future experimental station control systems.

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