The M_2&M_3 positioning control systems of a 2.5m telescope

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ABSTRACT

The 2.5m optical/infrared telescope is an F/8 telescope comprising one Cassegrain foci, two Nasmyth foci and two student Nasmyth foci. This paper presents a brief description of the physical structure, conceptual design, hardware implementing measure and software structure in the positioning control system of M_2&M_3. The graphical user interface application (Qt) is adopted to design the software. During the full working range the M_2 focus and decenter achieve the positioning repeatability is better than ±4μm and the M_2 tilt is better than 10 μrad. The M_3 angular positioning and locking accuracy is better than 10 arcsec and repeatability is better than 2 arcsec RMS.

Keywords: 2.5m telescope, M_2&M_3, positioning control, control systems

1. INTRODUCTION

The 2.5m optical/infrared telescope is an F/8 telescope comprising:

- ✓ One Cassegrain foci (C_1), 2 Nasmyth foci (N_1 and N_2) on which instruments can be mounted
- ✓ 2 student Nasmyth foci (N_3 and N_4) which are not equipped
- ✓ 3 mirrors: M_1 which is the primary mirror, M_2 which is the mirror at the top of the structure and M_3 which transfers light to the Nasmyth foci
- ✓ A Wide Field Corrector (WFC) fitting in C_1 and in N_1
- ✓ The mount system

This paper is mainly to introduce the positioning control systems of M_2 and M_3, including physical structure, hardware structure, software structure and the results of the test.

2. PHYSICAL STRUCTURE

2.1 M_2 positioning system

M_2 positioning system is used to correct the misalignment of the secondary mirror with respect to the primary mirror, which is mainly due to thermal effect and mechanical distortion induced by telescope elevation changes during the

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operation. The misalignment includes three factors: defocus (Δz), decenter (Δx, Δy) and tilt (Δθx, Δθy), total 5 freedoms. The 2.5m telescope equipped with a kind of series-parallel movement institution with five freedom to correct the main aberrations introduced by mirrors misalignment and distortions. The series-parallel institution is composed of support structure and control system. Support structure consists of three parallel and two orthogonal movement suit, mobile plate, fixed plate, and corresponding control system. M_2 cell is attached to mobile plate and the fixed plate is attached to center box of top ring. The weight of M_2 mirror and its cell is about 250Kg which is the load for series-parallel institution to support. Control system is applied to the structure to introduce the corresponding movements. Real-time capability, precision in positioning and smoothness of the movement are the main characteristics of the series-parallel institution control system. The M_2 positioning system structure is shown in fig.1.

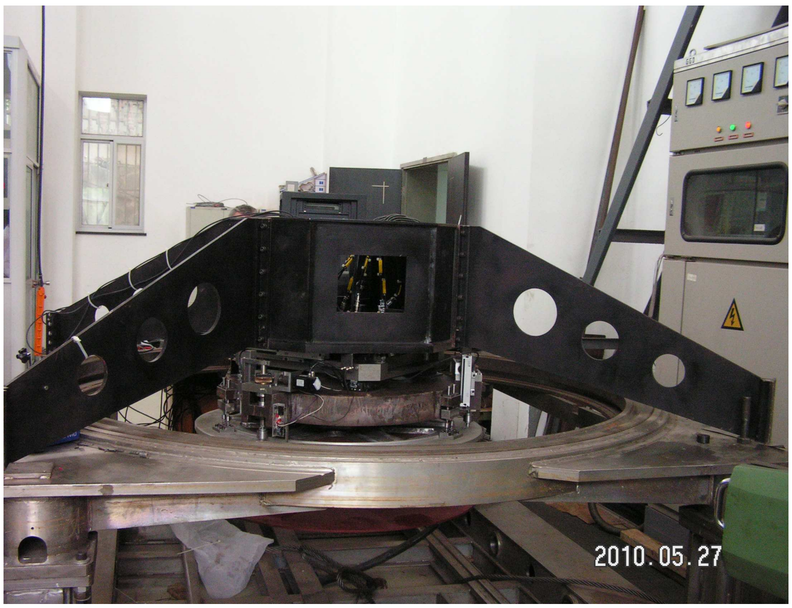

Fig.1 M_2 positioning system structure

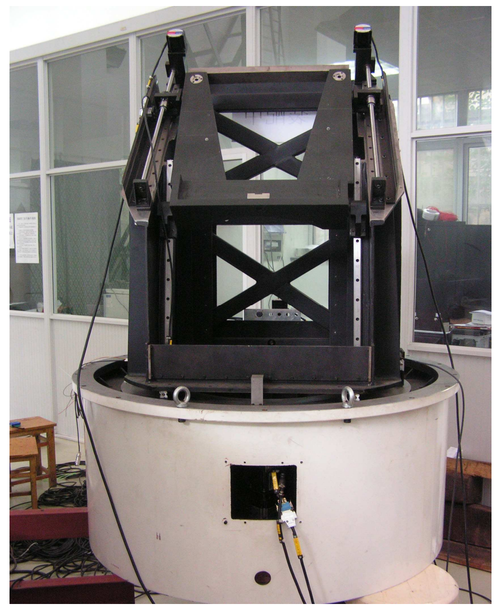

Fig.2 M_3 positioning system structure

2.2 M_3 positioning system

For the 2.5m telescope, there are two Nasmyth foci, two student Nasmyth foci and one Cassegrain foci. M_3 positioning system is used to transfer the light beam to these foci according to the observing arrangement and to ensure the alignment between optical elements.

This structure is mainly composed of three sub-parts: rotation unit, escape unit and translation unit. Escape motion just consists of two linear movements, because of the room left for M_3 escape is very small. M_3 cell is supported by a U shape welded supporting structure through 3 bolts. The supporting structure is optimized to ensure high stiffness and to keep M_3 cell free from outside stress. The supporting structure is positioned by 4 ball rails through 4 corresponding blocks of rails mounted on a stiffing pedestal. The motion is drived by the combination of worm gear and ball screw. Linear encoder is used to feedback the position information to control system. Switches and hard ends are used to ensure the safety of the motion. Besides the escape function, the tilt adjustment of the M_3 will also be fulfilled by this system. The motion of translation along Nasmyth axis is drived by slide screw along the ball screw rails. The position is controlled by linear encoder through motion control system. A spring is used to release the backlash of the slide screw. Rotation system is composed of supporting roller bearing, spur gear drive, driving motor and position feedback tape encoder. Two set of pinions are arranged 180° separately to release the backlash of the system and driven by two servo motors. The diameter of the gear is 900mm with 30 gear ratio. The M_3 positioning system structure is shown in fig.2.

3. HARDWARE STRUCTURE

The M_2&M_3 positioning control system is a distributed system including a host computer and two slave intelligent controllers. The Galil DMC-21x3 controller is used for the slave intelligent controller. The intelligent controller mainly realizes the closed-loop control of the servo motor, alarm signal processing and communication with IPC (Industrial control computer) by Ethernet.

3.1 Galil DMC-21x3 controllers

The Galil's DMC-21x3 Ethernet motion controller is designed for extremely cost-sensitive and space-sensitive application. The DMC-21x3 controllers is available with a variety of plug-in, multi-axis amplifier boards that are designed to eliminate the wiring and any connectivity issues between the controller and drives. Plug-in amplifiers are available for driving stepper, brush and brushless servo motors up to 500 Watts. The DMC-21x3 series is available in one through eight axis versions and can be configured for control of step or servo motors on any combination of axes. With a 32-bit microcomputer, the DMC-21x3 controllers provide such advanced features as PID compensation with velocity and acceleration feedforward, program memory with multitasking for simultaneously running eight applications programs, and uncommitted I/O for synchronizing motion with external events. Modes of motion include point-to-point positioning, position tracking, jogging, linear and circular interpolation, contouring and electronic gearing.

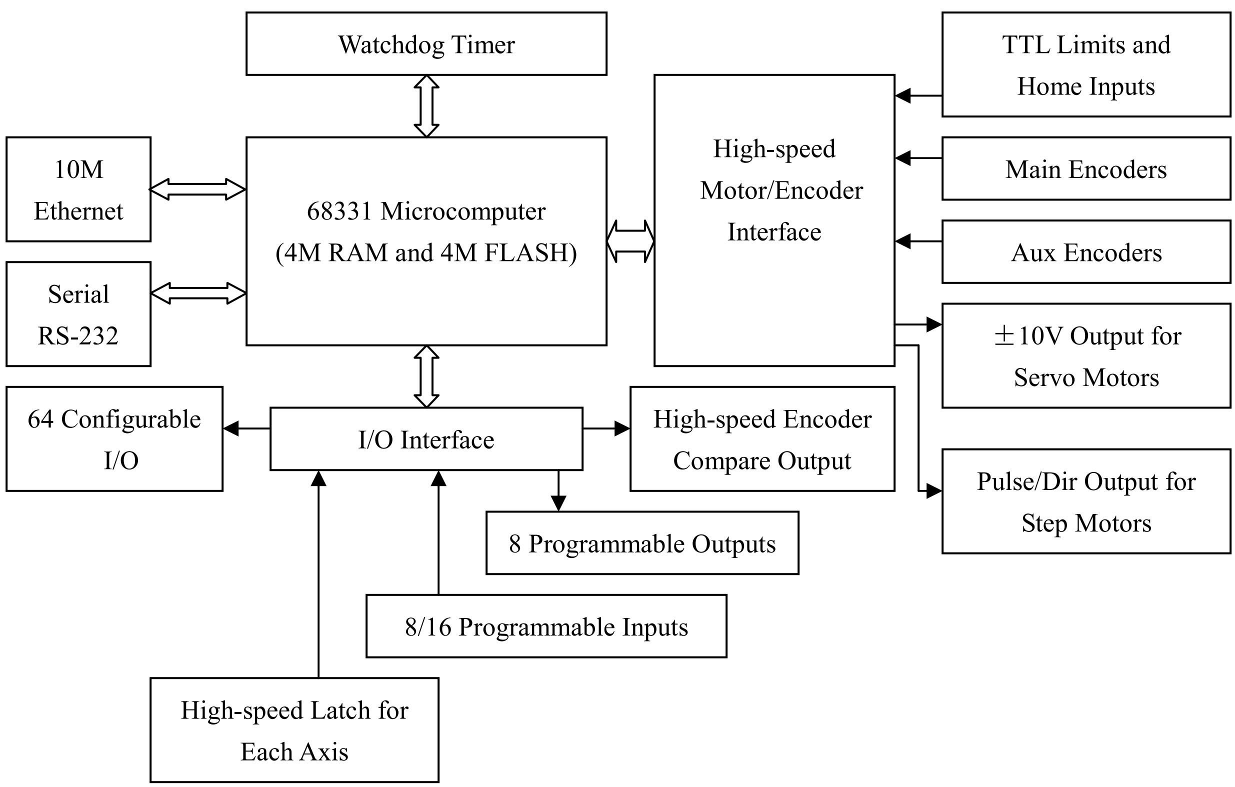

Fig.3 DMC-21x3 Functional Elements

In order to convenient for connection and higher reliability, the ICM-20105 opto-isolated I/O module is used with

DMC-21x3 controllers. It has four 15-pin Male D-Sub connectors for individual axis signals. There is one 37-pin D-Sub for the 8 digital inputs, 8 high side drive 500 mA digital outputs, home switches, limit switches, and one 25-pin D-Sub for 4 axes of auxiliary encoders. Programming the DMC-21x3 is simplified with two-letter, intuitive commands and a full set of software tools such as GalilTools for servo tuning and analysis.

3.2 M_2 hardware structure

The Galil2163 (6 axes) will control the M_2 subsystem of the drives of the motors via +/-10V signals (analog). The axes of M_2 subsystem (X centering, Y centering, X tilt, Y tilt, Focusing) will be controlled under the servo loop architecture. And X tilt motion, Y tilt motion and focusing motion are made as a result of combination motions of these 3 axes (A tilt, B tilt, and C tilt). The hardware structure of X centering and Y centering is the same. And the other 3 axes are the same. The architecture of the M_2 control system is shown in fig.4.

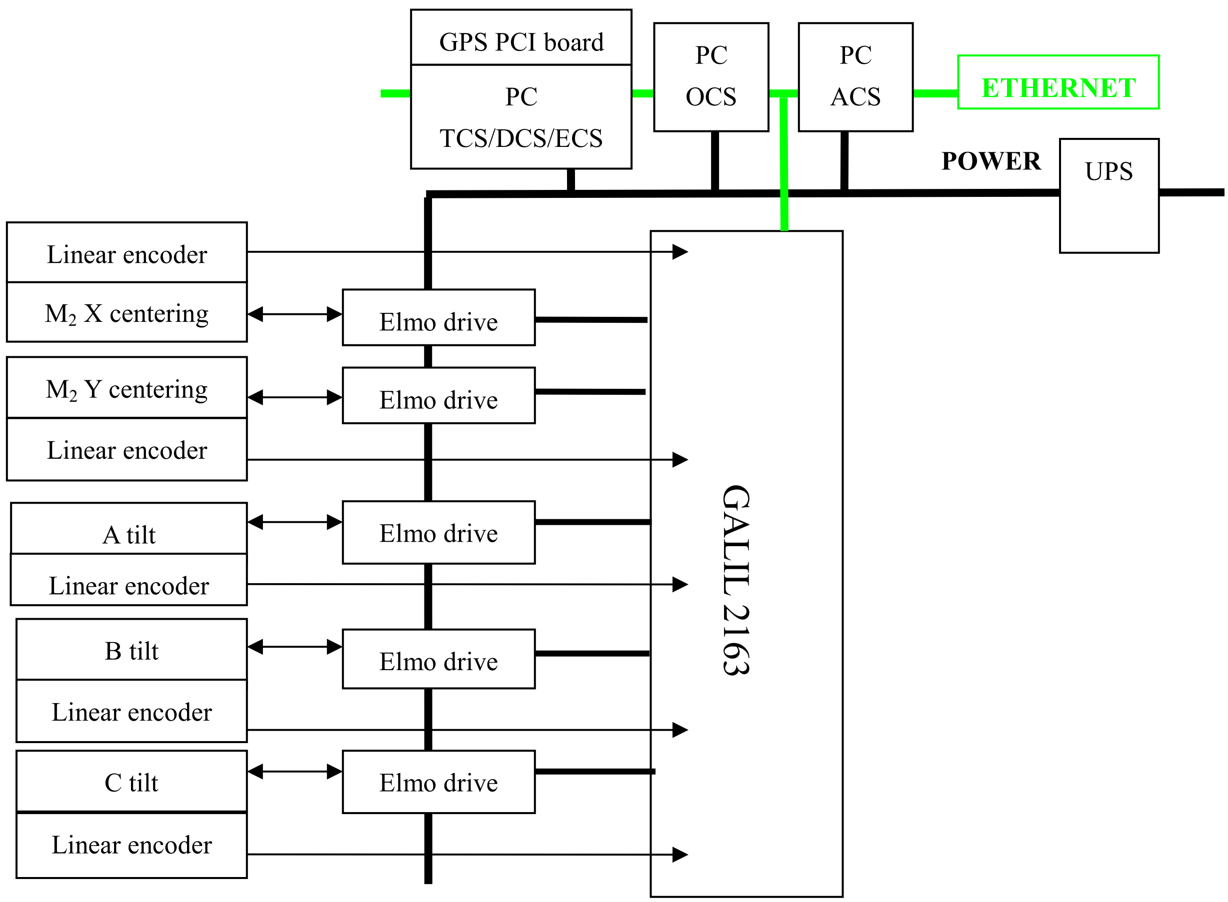

Fig.4 Architecture of the M_2 control system

3.2.1 X centering and Y centering

✓ Motor

AKM 21C - Brushless motors from Kollmorgen

Total driven load : ≈ 4.2 N.m

Total ratio of reducing : 20

Peak torque needed : 0.24 N.m

Nominal torque of the motor : 0.48 N.m (peak torque 1.47 N.m)

- ✓ Amplifier

Harmonica 2/200 from ELMO

- ✓ Encoder for position

LIS 73-1 from Numerik Jena, precision +/-2 µm

- ✓ Encoder for motor commutation (back encoder)

Encoder TTL 2048 pulse/ rev

3.2.2 A tilt, B tilt and C tilt

- ✓ Motor

AKM 11B - Brushless motors from Kollmorgen

Total driven load : ≈ 0.5 N.m

Total ratio of reducing : 50

Peak torque needed : 0.01 N.m

Nominal torque of the motor : 0.183 N.m (peak torque 0.609 N.m)

- ✓ Amplifier

Harmonica 2/200 from ELMO

- ✓ Encoder for position

LIS 73-1 from Numerik Jena, precision +/-2 µm

- ✓ Encoder for motor commutation (back encoder)

Encoder TTL 2048 pulse/ rev

3.3 M_3 hardware structure

The Galil2183 (8 axes) will control the drives of the motors via +/-10V signals (analog) for brushless motors. This Galil will control the axes of the M_3 subsystem and the balance subsystem (total 7 motors controlled). A rotating and escapable M_3 mirror unit distributes the light towards the four Nasmyth foci through the elevation axles.

3.3.1 M_3 rotation

- ✓ Motor

2 motors AKM 21C - Brushless motors from Kollmorgen

Total load driven : ≈ 133 N.m

Total ratio of reducing : 280

For each motor:

Peak torque needed after reduction : ≈ 0.24 Nm

Nominal torque of each motor : 0.48 N.m (peak torque 1.47 N.m)

- ✓ Amplifier

Harmonica 2/200 from ELMO

- ✓ Encoder for position

Rotary encoder Heidenhain ERA 880 C.

36000 lines. Accuracy +/-3” Arc sec

- ✓ Encoder for motor commutation(back encoder)

Encoder TTL 2048 pulses/rev

3.3.2 M_3 escape

✓ Motor

2 motors JSF-60–AC servo motors from Bonmet

For each motor peak torque needed : 0.028Nm

Nominal torque of each motor : 0.5N.m

✓ Amplifier

SA3L04C from Bonmet

✓ Encoder for position

LIDA573 from Heidenhain, precision +/-2 µm

✓ Encoder for motor commutation(back encoder)

Encoder TTL 1000 pulses/rev

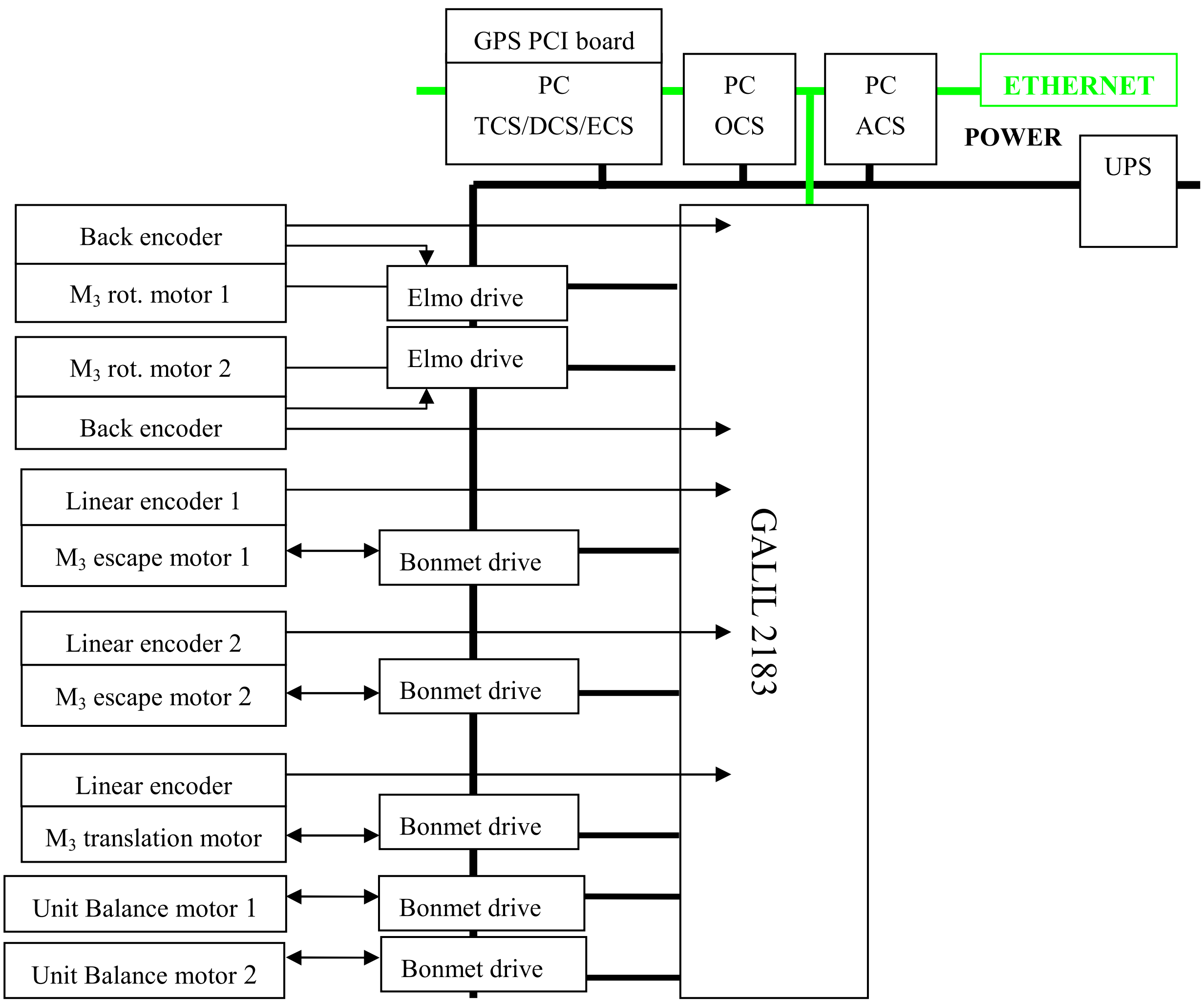

Fig.5 Architecture of the M_3 control system

3.3.3 M_3 translation

✓ Motor

1 motors JSF-60–AC servo motors from Bonmet

Total driven load : 2.7 N.m

Total ratio of reducing : 10

Peak torque needed : 0.27Nm

Nominal torque of the motor : 0.5N.m

✓ Amplifier

SA3L04C from Bonmet

✓ Encoder for position

LIS 73-1 from Numerik Jena, precision +/-5 µm

✓ Encoder for motor commutation(back encoder)

Encoder TTL 1000 pulses/rev

3.3.4 Unit balance

✓ Motor

2 motors JSF-60–AC servo motors from Bonmet

Peak torque needed : 0.013Nm

Nominal torque of each motor : 0.5N.m

✓ Amplifier

SA3L04C from Bonmet

✓ Encoder for motor commutation(back encoder)

Encoder TTL 1000 pulses/rev

4. SOFTWARE STRUCTURE

The M_2&M_3 positioning control systems software consists of two parts. One is written by Qt4.0 and runs on an industrial control computer (IPC) under FEDORA11. The other is real-time two-letter commands program which runs on Galil. IPC-embedded software is designed object-oriented with the advantages of easy to develop and debug and has three major tasks, namely sending commands to Galil, exchanging data with Galil through DPRAM, providing a graphic user interface.

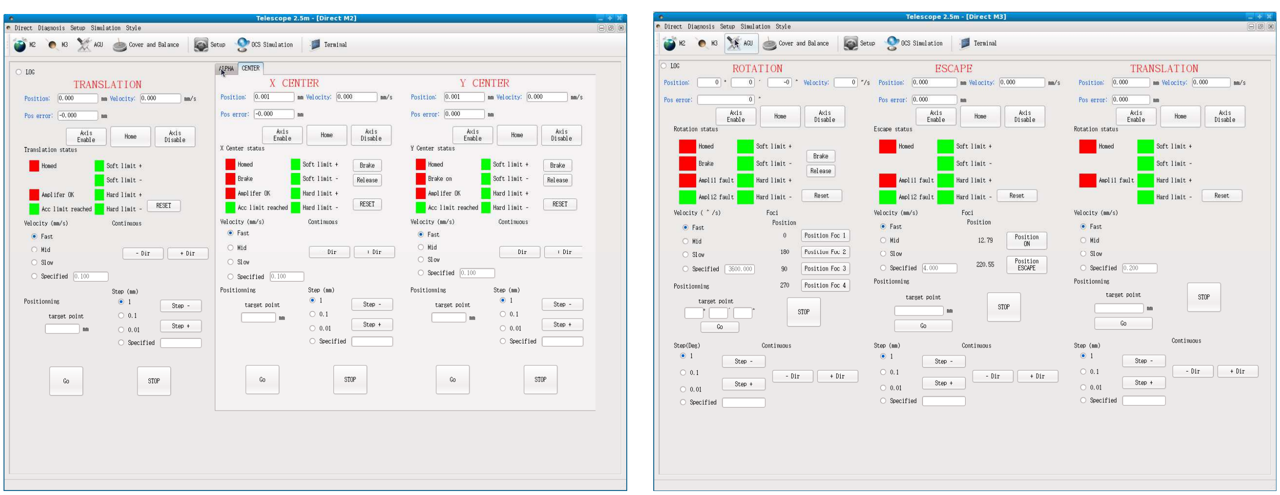

Fig.5 software interface of the M_2 & M_3 control system

IPC-embedded software is divided into parallel sub-module which is independent of each other in accordance with the controlling hardware unit. After system startup, the programs regularly check the work status of every component in this system and send alarm information automatically. In order to achieve all operating functions, it is need to know how every motor or every axis works because motor is the essential part of the hardware unit. Because the underlying control program has been downloaded to the controller, the controller could achieve closed-loop control just base on a value which is given by IPC-embedded software. In order to reflect the implementation process and results of the operations, IPC-embedded software needs to callback the current status or position information of every motor or axis from controller. In addition, IPC-embedded software has the function of communication with main control system. The fig.5 shows the software interface of the M_2 & M_3 control system.

5. TEST AND CONCLUSION

The precision test of M_2&M_3 positioning control systems uses an auto-collimator. During the full working range the M_2 focus and decenter achieve the positioning repeatability is better than ±4μm and the M_2 tilt is better than 10 μrad. The M_3 angular positioning and locking accuracy is better than 10 arcsec and repeatability is better than 2 arcsec RMS. The specific test results are shown in the table1.

Table 1 the results of the test

Item			Requirement	Test results
M2	Decenter	Range	±6mm	±10mm
		Resolution	1um	0.1um
		Repeatability	±10um	±3um
	Tilt	Range	±1°	±1.8°
		Resolution	2urad	0.2urad
		Repeatability	±10urad	±7.5urad
	Focus	Range	±8mm	±15mm
		Resolution	1um	0.1um
		Repeatability	±4um	±3um
M3	Rotation	Range	270 °	280 °
		Resolution	1arcsec	0.2arcsec
		Repeatability	2arcsec	1arcsec
	Escape	Range	480mm	560mm
		Resolution	1um	0.1um
		Repeatability	10um	3um
	Translation	Range	5mm	10mm
		Resolution	0.01mm	1um
		Repeatability	0.01mm	4um

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