Control System of Position actuators For Segmented mirror active optics in LAMOST

Xixia Du*[a,b],Zhenchao Zhang[a], Yongjun Qi[a], Aihua Li[a]
[a] National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing 210042
[b]Graduate School of the Chinese Academy of Sciences, Beijing 100049

ABSTRACT

This paper presents an implementation of control system of position actuators in LAMOST. Performance of actuators has been tested in laboratory. The resolution of actuators is less than 5nm. The whole control system has been successfully realized in LAMOST M_B pre-segmented experiment. The control system of position actuator adopts distributed-and-centralized mode. Displacement RMS error of the control system (including actuator and electrical control) is less than 50 nm.

Keywords: Active optics ,Actuator, Networks, LAMOST

1. INTRODUCTION

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) is a quasi-meridian reflecting Schmidt telescope[1]. One of its innovations is the pioneering application of segmented mirror active optics in both the reflecting Schmidt corrector plate Ma and the spherical primary mirror Mb. Ma is 5.72 meters long and 4.40 meters wide, which is composed of 24 plane hexagonal sub-mirrors. Mb is 6.67 meters long and 6.05 meters wide, which is composed of 37 spherical hexagonal sub-mirrors. Position actuators are the key components of segmented mirror active optics. In order to keep all the sub-mirrors co-focus, three position actuators are mounted on the back of each sub-mirror to modify the piston/tip/tilt degrees of freedom.

183 actuators, which are distributed on Ma and Mb, need to be actively controlled. Distance between Ma and Mb is about 40 meters. Remarkable features of control system are a large number of devices, and a large physical area of coverage. A large physical area also requires a large amount of wiring among devices. Therefore, it is difficult to implement the traditional point-to-point connections to a simple centralized control unit in these complex systems[2].

Considering all these factors, we apply distributed-and-centralized control method[3,4]. This control mode requires less complex wiring, reduces the setup and maintenance costs and also makes convenience of diagnostics.

2. ACTUATOR CONTROL SYSTEM ARCHITECTURE

As shown in Fig.1, the whole actuators control system can be divided into subsystem Ma and subsystem Mb. Two subsystems are controlled by active optics workstation. There is a master station and several intelligent controllers in each subsystem. Intelligent controllers are connected to master station with Ethernet interface on their own masterboard through switch. Each controller controls six sets of actuators.

3rd International Symposium on Advanced Optical Manufacturing and Testing Technologies:
Large Mirrors and Telescopes, edited by Yudong Zhang, Wenhan Jiang, Myung K. Cho
Proc. of SPIE Vol. 6721, 672106, (2007) · 0277-786X/07/$18 · doi: 10.1117/12.782688

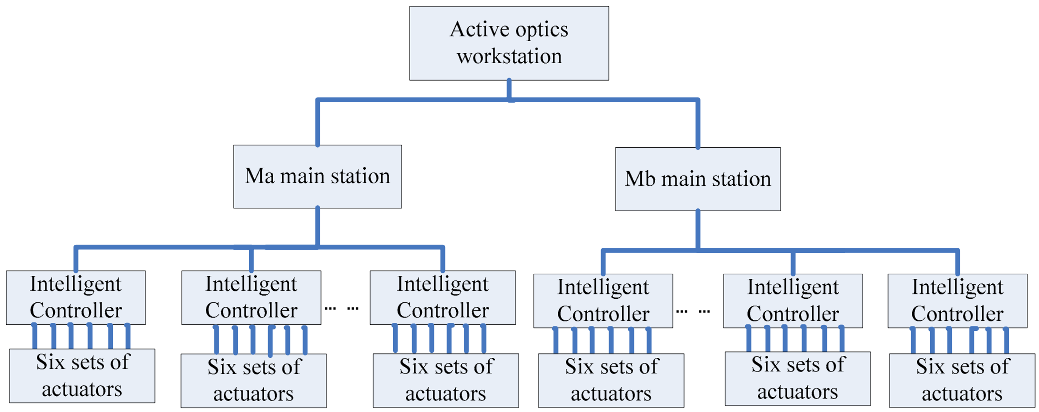


Fig.1 Block diagram of control system of actuators

Fig.2 shows the network topology of Ma and Mb subsystem.

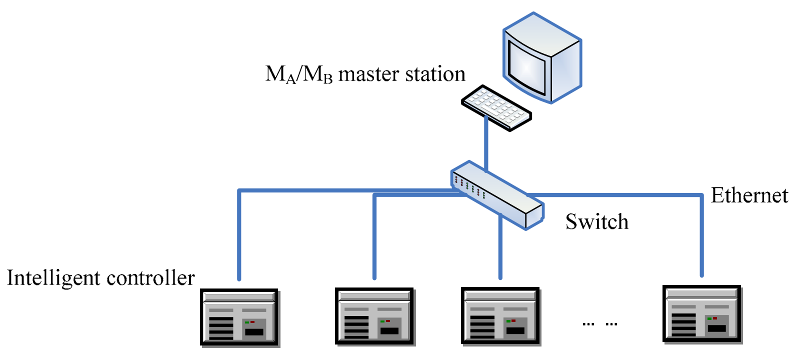


Fig. 2 Network topology of actuator control subsystem

3. ALGORITHM OF POSITION ACTUATORS CONTROL

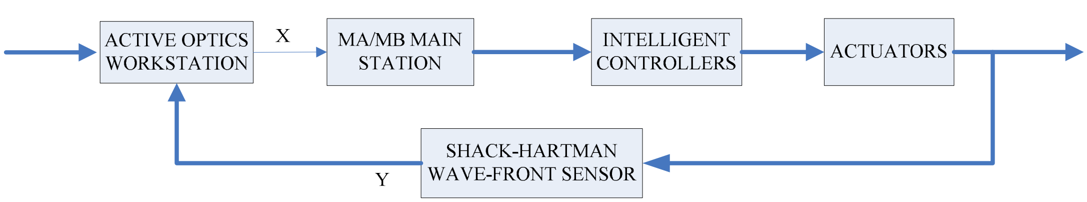


Fig.3 Block diagram of control algorithm

As shown in Fig.3, we get test and correction equations from Shack-Hartmann wavefront measurement [5] :

$$
\begin{cases}
a_{11}x_1 + a_{12}x_2 + \cdots\cdots a_{1m}x_i = y_1 \\
a_{21}x_1 + a_{22}x_2 + \cdots\cdots a_{2m}x_i = y_2 \\
\cdots\cdots \\
a_{n1}x_1 + a_{n2}x_2 + \cdots\cdots a_{nm}x_i = y_j
\end{cases}
\tag{1}
$$

Written in matrix form：

$$
A\vec{X} = \vec{y} \tag{2}
$$

X is the displacement of each position actuator. A is the displacement coefficient matrix, which can be obtained by measurements or calculation and stored in active optics workstation.

Use the method of least square and apply Gauss elimination, we get the following equation.

$$
A^T A\vec{X} = A^T \vec{y} \tag{3}
$$

X can be solved from this equation.

4. SOFTWARE CONFIGURATION

M_A/M_B master station:

Operating system:WINDOWS2000 Programming environment:VC++6.0

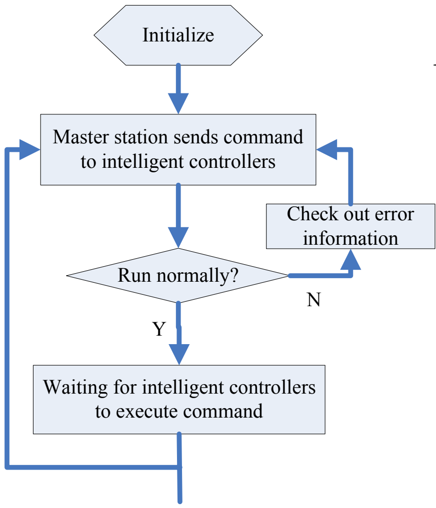
- Design friendly GUI
- Realize communication with Winsock based on TCP/IP

Intelligent controller：

Operating system: MS-DOS 6.22 Programming environment:TC++3.0

- Realize communication with Dsock based on TCP/IP
- Control the stepper motors of position actuators

Basic function of software has already successfully been realized in the laboratory. Fig.4 and Fig.5 show the flowchart[6] of each module.



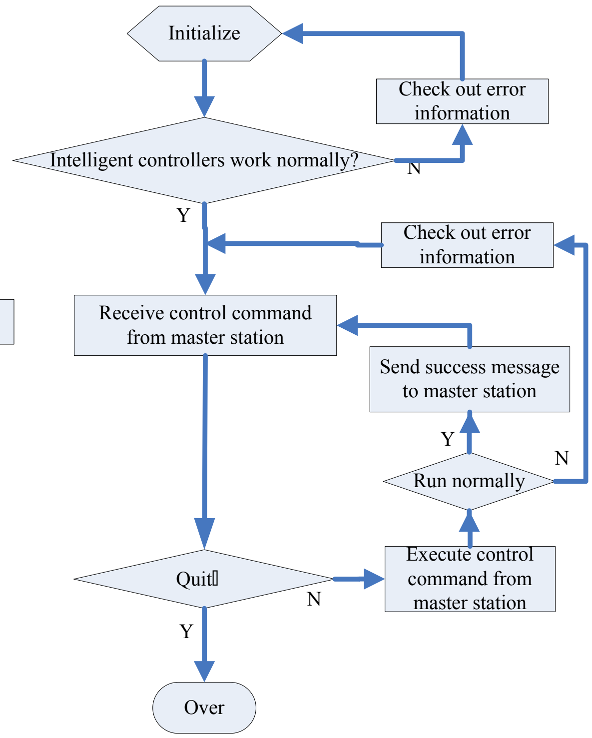


Fig. 4 Program flowchart of the M_A/M_B master station   Fig.5 Program flowchart of intelligent controllers

5. TEST EXPRIMENTS OF POSITION ACTUATORS

5.1 Experiment principle

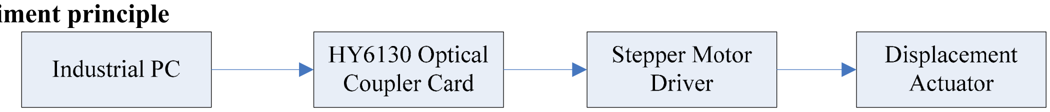


Fig.6 Principle of experiment block diagram

Position actuators with stepper motor are used in LAMOST. The motor driver is programmed in C language. It gives direction and pulses to actuators. Signal is outputted from industrial computer(See Fig.6). Displacement is measured by Laser interferometer. All the tests are performed on Micro-displacement working platform with nanometer resolution.

5.2 Experimental results and Discussion

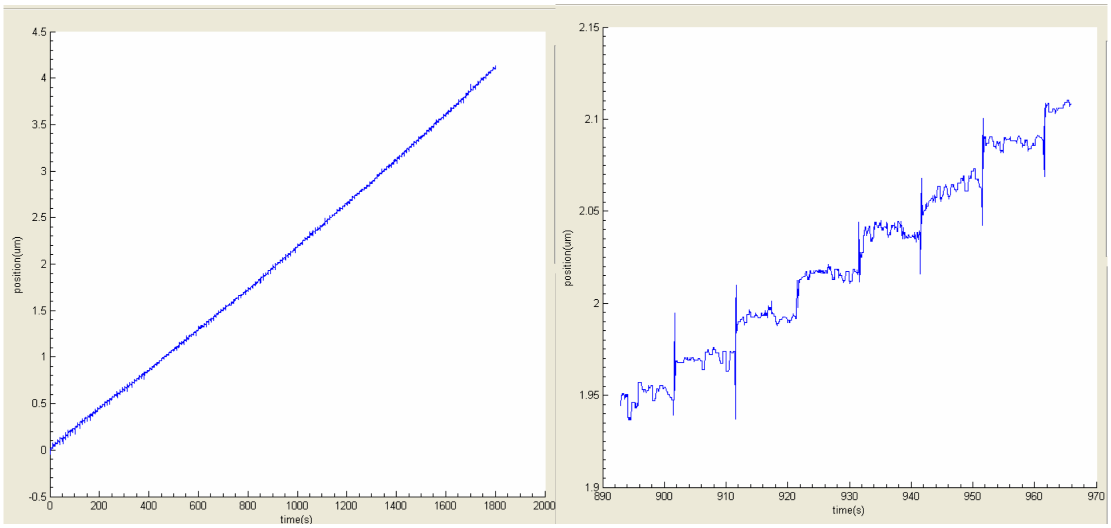


Fig.7 Displacement curve of 3# actuator (left picture is amplied)

（experiment conditions：16steps per cycle，forward; results: resolution 1.4259nm,RMS 5.551nm）

Some statistical results are shown in the table below.

Table 1: Actuator resolutions (units: nanometer)

steps	Actuator 1#		Actuator 2#		Actuator 3#		Actuator 4#		Actuator 5#	
	Forward	Backward	Forward	Backward	Forward	Backward	Forward	backward	forward	backward
16	1.769	1.5035	1.444	1.5025	1.4259	1.4021	1.6935	1.4478	1.5904	1.3743
32	1.7581	1.5677	1.5906	1.5673	1.6946	1.3934	1.6605	1.4832	1.6044	1.3888
320	1.658	1.756	1.81	1.647	1.6916	1.6383	1.6608	1.7101	1.7921	1.7780
1250	1.704	1.6	1.6896	1.573	1.6762	1.5554	1.6885	1.6131	1.7507	1.7507
Average resolution	1.6645		1.603		1.5597		1.6196		1.6287	

Table 2:Standard deviation of Actuators (units: nanometer)

steps	Actuator 1#		Actuator 2#		Actuator 3#		Actuator 4#		Actuator 5#	
	Forward	Backward	Forward	Backward	Forward	Backward	Forward	Backward	Forward	Backward
16	5.37	6.109	5.179	4.827	5.551	5.355	5.264	4.599	4.48	4.601
32	6.826	5.868	4.486	5.515	5.230	6.102	4.627	5.191	5.180	4.543
320	28.414	16.493	19.151	26.503	15.596	24.304	19.59	27.772	42.144	48.394
1250	65.978	74.2	147.79	150.85	105.54	187.22	42.147	42.673	73.046	106.11

Table 3: Actuator backlash(units: micron meter)

backlash / direction	Actuator 1#	Actuator 2#	Actuator 3#	Actuator 4#	Actuator 5#
Forward to Backward	1.072	1.041	1.007	0.957	2.656
Backward to Forward	1.027	1.319	1.291	1.024	3.010

The resolution of position actuators is around 1.6 nm. Actuators can work with high resolution and precision. The backlash exits in position actuators when the direction of motion is changed, as shown in Fig.7. In order to solve this problem, the exact backlash of each actuator is measured and stored in a look-up table(See Table 3).

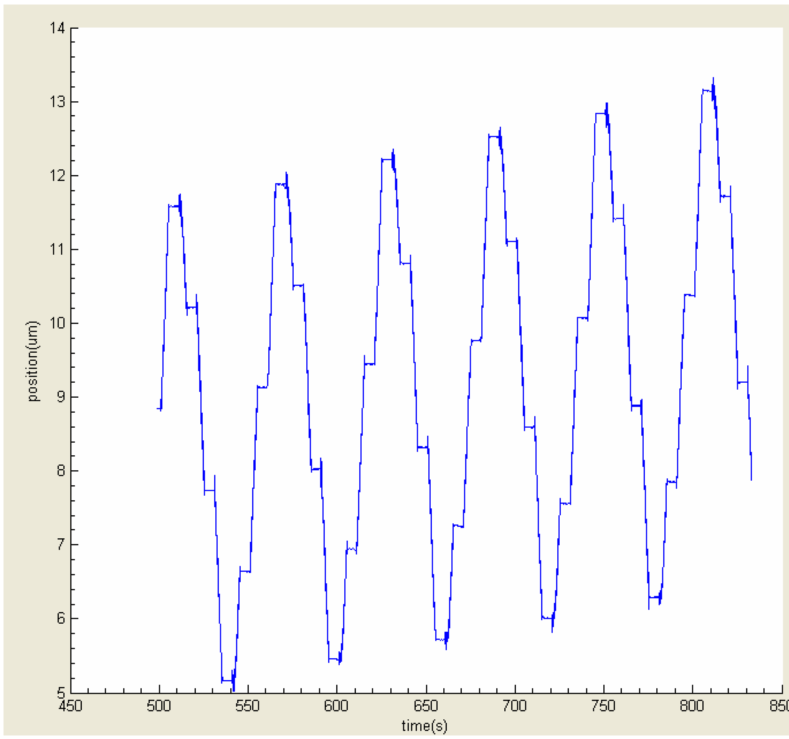


Fig.8 Backlash of 3# actuators

(experiment conditions：1750steps per cycle，forward three cycles and backward three cycles； backlash occurs when the direction is changed)

6. CONCLUSION

So far, co-focus experiment of three segmented sub-mirrors of Mb has been done successfully. The accuracy of co-focus can reach up to about 0.4 arc-sec, which well satisfies the technical requirements of LAMOST. Nine actuators which have been tested in the laboratory, are mounted on the back of three sub-mirrors of Mb. The prototype of control system described before has been applied. Mb master station receives displacement message calculated by the Shack-Hartmann wave front test, compensates for backlash through a pre-generated look-up table and then sends final displacements to intelligent controllers which drive actuators to make precise movements. For control system, the resolution of position actuators is less than 5 nm. Displacement RMS error of control system (including actuator and electrical control) is less than 50 nm. Experimental results indicate that control system of actuators is practicable and feasible.

ACKNOWLEDGEMENTS

This research is supported by Large Sky Area Multi-Object Fiber Spectroscopic Telescope Project, which is on of the major on-going national large scientific projects in China.

REFERENCES

1. Chinese Academy of Sciences, “Large Sky Area Multi-Object Fiber Spectroscopic Telescope origin survey”, 1997.
2. Feng-Li Lian, John K.Yook, Dawn M.Tilbury, James Moyne, “Network architecture and communication modules for guaranteeing acceptable control and communication performance for networked multi-agent systems”,*IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS,*VOL.2,NO.1, 2006.
3. Zhenchao Zhang, “Electrical Control System Scheme for Active Optics of M_A in LAMOST”，*LAMOST Internal Technical Report*，No.**LAMOST-TR-NAIRC-L5-007**, 2001.
4. Zhenchao Zhang, You Wang, Wenzhi Zong, “Control System of Optical Testing Device of Thin Mirror Active Optics”，*LAMOST Internal Technical Report*, 2005.
5. Ding-qiang Su, Xiangqun Cui, Ya-nan Wang, Zhengqiu Yao, “Large sky Area Multi-object Fiber Spectroscopic Telescope and its key technology”, *Proc. SPIE* 3352,76-90, 1998.
6. Zhenchao Zhang, You Wang, “Electrical Control System Scheme of force actuators for Active Optics in LAMOST”，*LAMOST Internal Technical Report*，No.**LAMOST-TR-NIAOT-L5-031**, 2005.