



The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST)

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June 2005, Beijing

Introduction

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) project as one of the National Major Scientific Projects undertaken by the Chinese Academy of Science. LAMOST is a quasi-meridian reflecting Schmidt telescope laid down on the ground with its optical axis fixed in the meridian plane. The aperture of LAMOST is 4m, enabling it to obtain the spectra of objects as faint as down to $20^m.5$ with an exposure of 1.5 hour. Its focal plane is 1.75m in diameter, corresponding to a 5° field of view, may accommodate as many as 4000 optical fibers. So the light from 4000 celestial objects will be led into a number of spectrographs simultaneously. Thus the telescope will be the one that possesses the highest spectrum acquiring rate in the world.

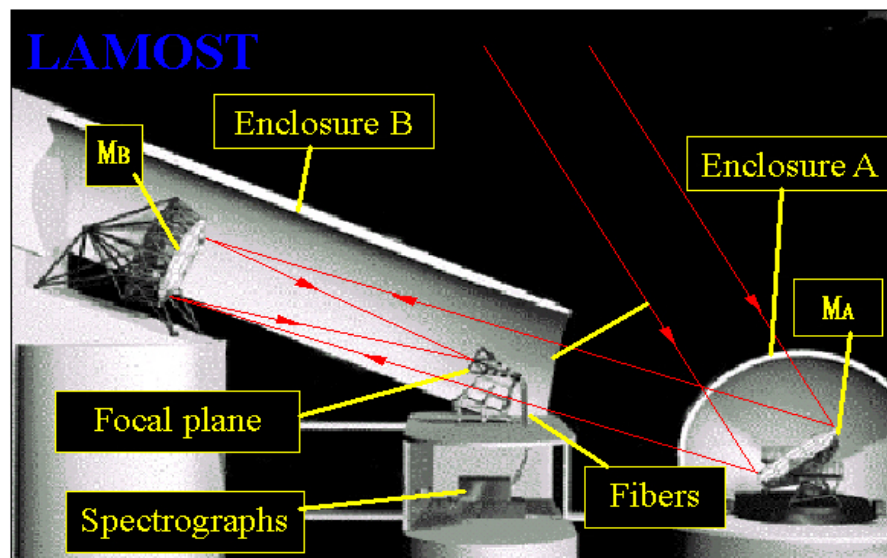
LAMOST adopts the active optics technique both for thin mirror and segmented mirror on the Schmidt corrector M_A , as well as the parallel controllable fiber positioning system. With these new concepts and design, LAMOST is expected to be a unique astronomical instrument in combining a large clear aperture and wide field of view.

The engineering of LAMOST consists of eight subsystems, optic system, active optics and mirror supporting system, mounting and tracking system, telescope control system, focal plane instruments, telescope enclosure, observatory control and data processing, and input catalogue and survey strategy. The project will come into operation at the end of 2007.

The telescope will be located at the Xinglong Observing Station of National Astronomical Observatories, Chinese Academy of Sciences. As a national facility, LAMOST will be opened to the whole Chinese astronomical community. Along with the completion of the construction at the beginning of the 21st century, LAMOST will bring Chinese astronomy to a leading position in the large scale observations of optical spectra, and in the research field of wide field astronomy.

As shown in the following figure, LAMOST consists of a reflecting Schmidt corrector M_A at the northern end, a spherical primary mirror M_B at the southern end and a focal plane in between. Both the primary mirror and the focal plane are fixed on their ground bases, and the reflecting corrector tracks the motion of celestial objects. Celestial objects are observed around their meridian passages. The light collected is reflected from M_A to M_B , again reflected by M_B and forms image of the observed sky on the focal plane. The light of individual objects is fed into the front ends of optical fibers accurately positioned on the focal plane, and then transferred into the

spectrographs fixed in the room underneath, to be dispersed into spectra and recorded on the CCD detectors, respectively and simultaneously.



The southern part of the telescope is higher than the other end, with its optical axis tilted by an angle of 25° to the horizon for the sky coverage. The declination of observable sky area ranges from -10° to $+90^\circ$.

Clear aperture	4m
Field of view	5°
Focal plane	ϕ 1.75m
Focal length	20m
Number of fibers	4000
Spectral ranges	370-900nm
Spectral resolution	1/0.25nm
Observable sky	-10° to $+90^\circ$ Declination

Main Characteristics of LAMOST

Scientific Goal of LAMOST

How has the universe been formed and evolved? The Milky Way, our own galaxy, consists of several tens of billions of stars. How has it been formed and evolved? In the whole history of human civilization, these basic and profound questions inspire people to explore the nature.

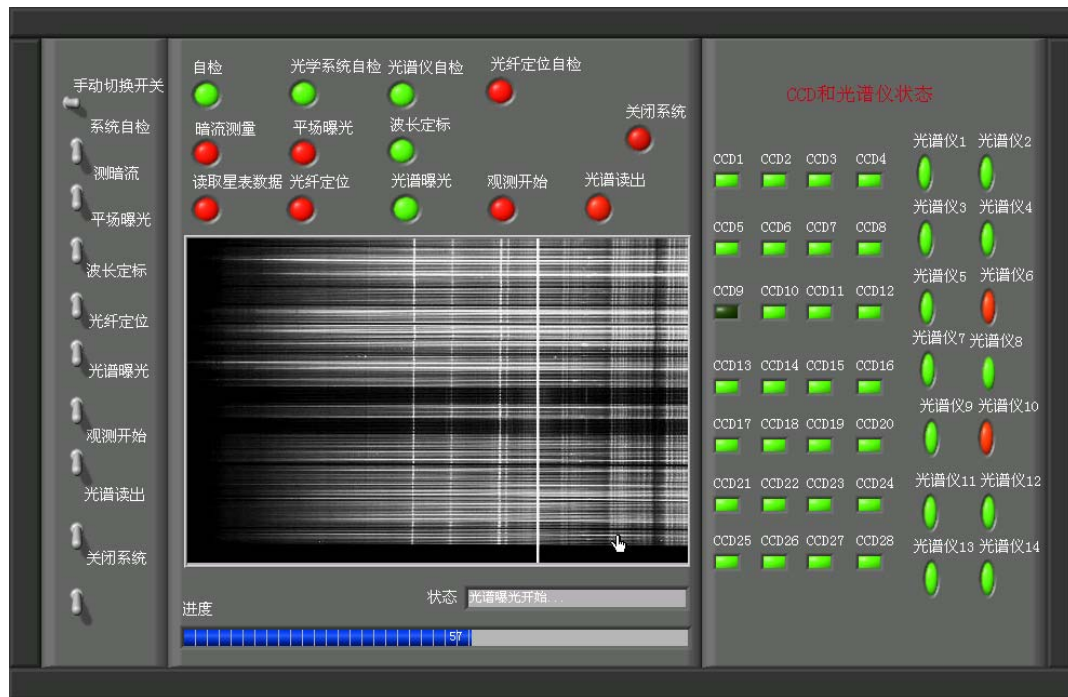
The optical spectrum contains abundant physical information of distant celestial objects, and acquiring spectra of a large number of celestial objects is desperately needed in astronomy, which touches various cutting-edge researches of contemporary astronomy and astrophysics.

The scientific goal of LAMOST focuses on the extragalactic observation, structure and evolution of the Galaxy, and multi-wave identification. The spectroscopic survey carried out by LAMOST of tens of millions of galaxies and others will make substantial contribution to the study of extra-galactic astrophysics and cosmology, such as galaxies, quasars and the large-scale structure of the universe. Its spectroscopic survey of large number of stars will make substantial contribution to the study of stellar astrophysics and the Galaxy. Its spectroscopic survey combining with the surveys in other wavebands, such as radio, infrared, X-ray and γ -ray will make important contribution to the cross-identification of multi-waveband of celestial objects.

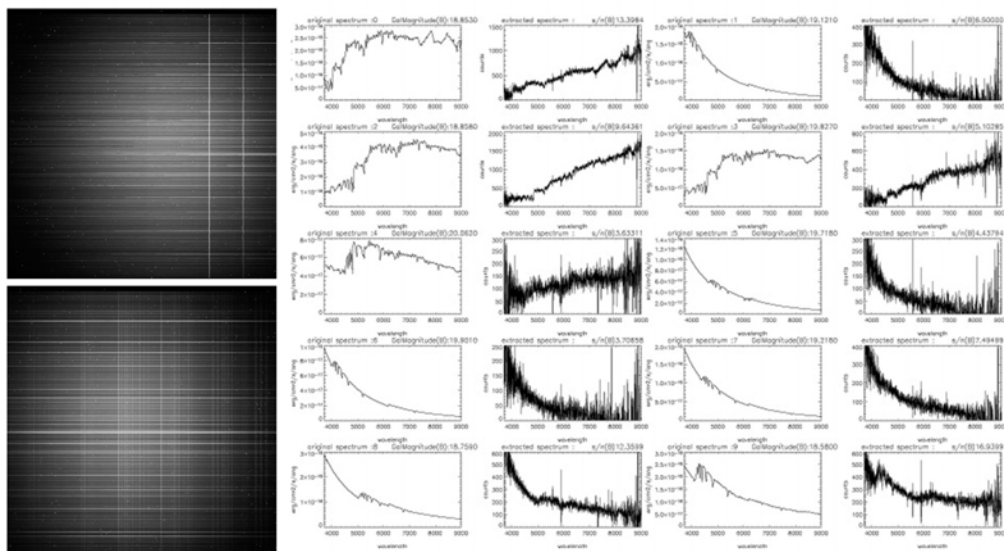
The large sample spectroscopic sky survey has been made dramatic progress in recent years, especially due to the success of 2dF and SDSS projects. With its powerful spectroscopic survey ability, LAMOST is expected to push it deeper and wider.

Observatory Control and Data Processing

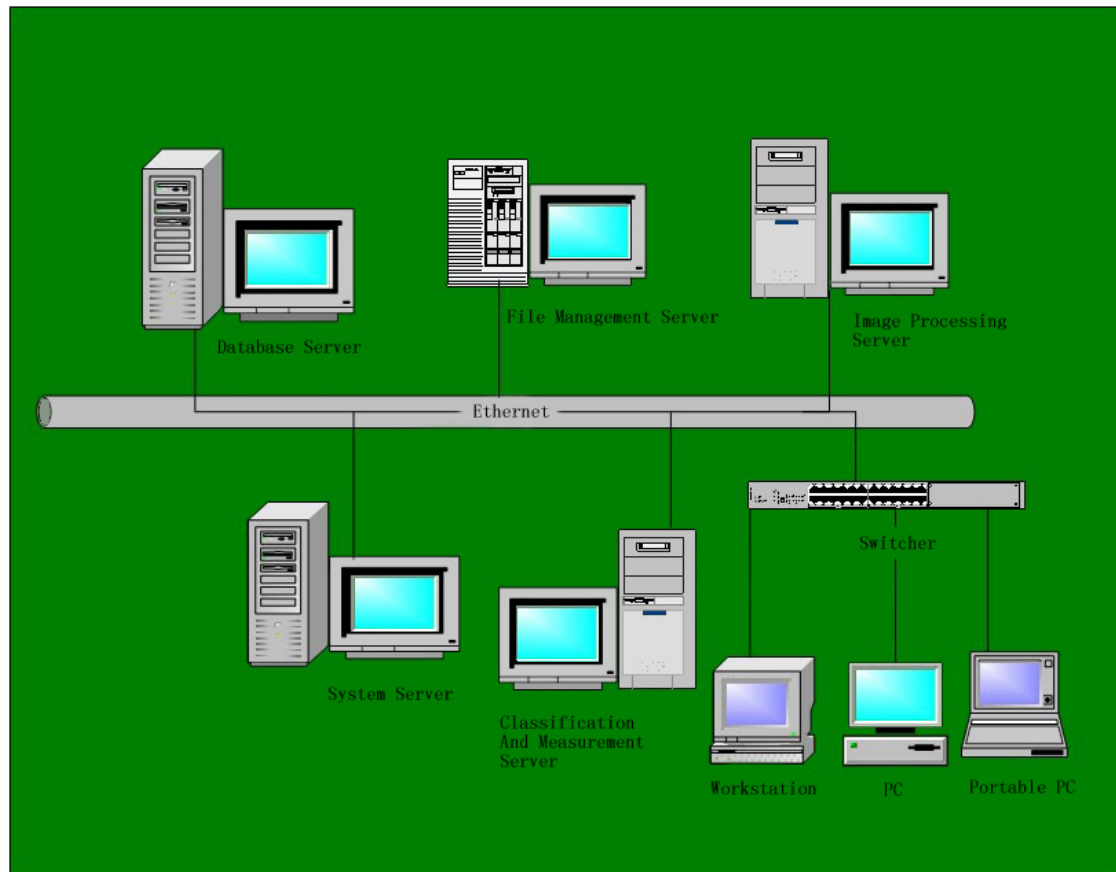
LAMOST will obtain up to ten-thousands of spectra per night and the data volume will be several gigabytes. It is planned to acquire ten-millions of spectra as a whole. In order to obtain the data high efficiently and gain more scientific results, LAMOST should have an automatic software system for its observation and data processing. For this purpose, a set of software system for observation, process and storage, including Survey Strategy System (SSS), Observation Control System (OCS) and Data Processing System (DPS) have being developed.



The interface of OCS



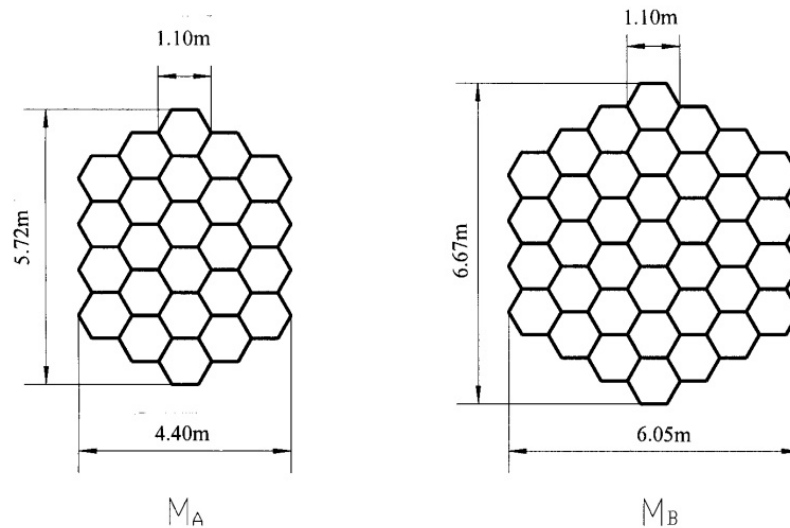
Simulation of 2D spectra and extracted 1D spectra



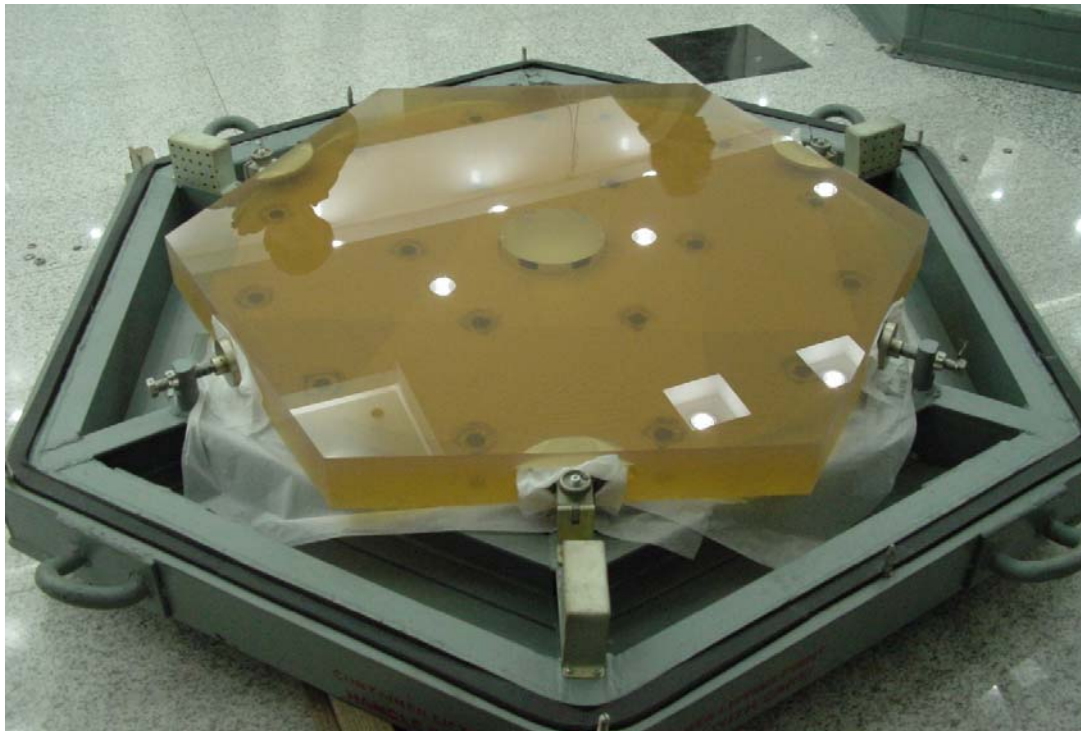
Topology of spectral analysis system

Optical System

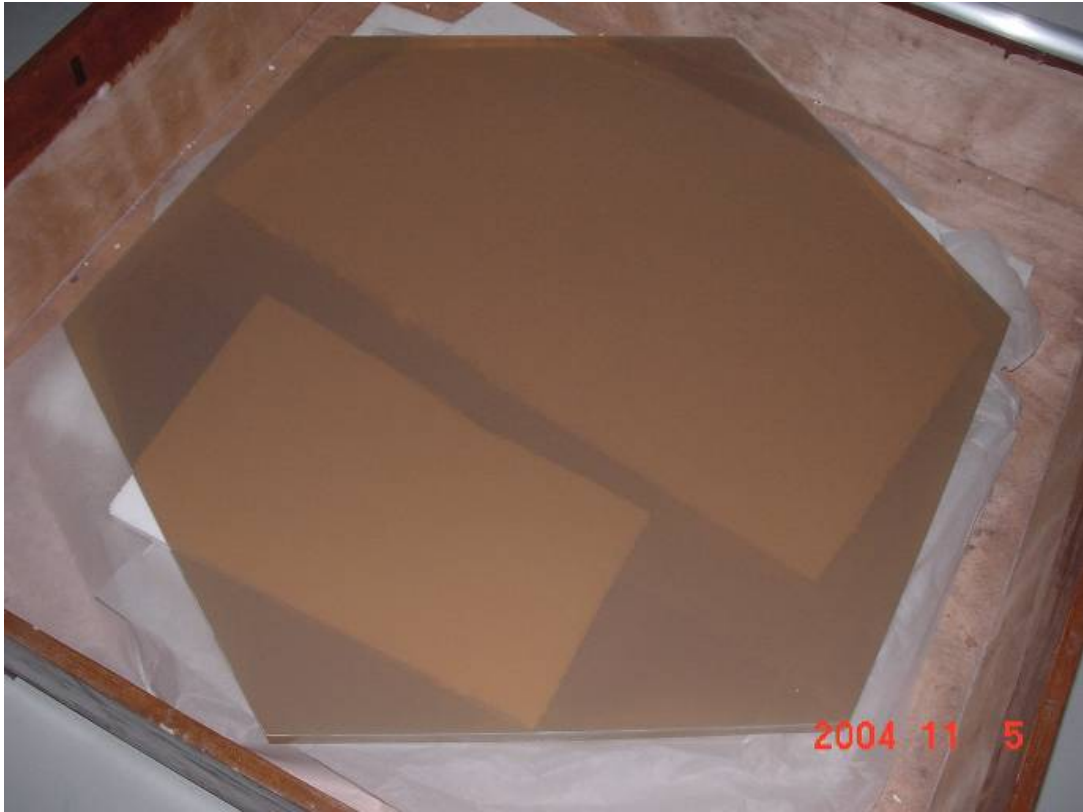
LAMOST optical system consists of a reflecting Schmidt corrector M_A at the northern end, a spherical primary mirror M_B at the southern end and a focal plane in between. The light collected is reflected from M_A to M_B , and then reflected by M_B and forms image of the observed sky on the focal plane. Both the primary mirror and the focal plane are fixed on their ground bases, and the reflecting corrector tracks the motion of celestial objects. Celestial objects are observed around their meridian passages.



Left, The reflecting Schmidt corrector (M_A), Right: The primary mirror (M_B)



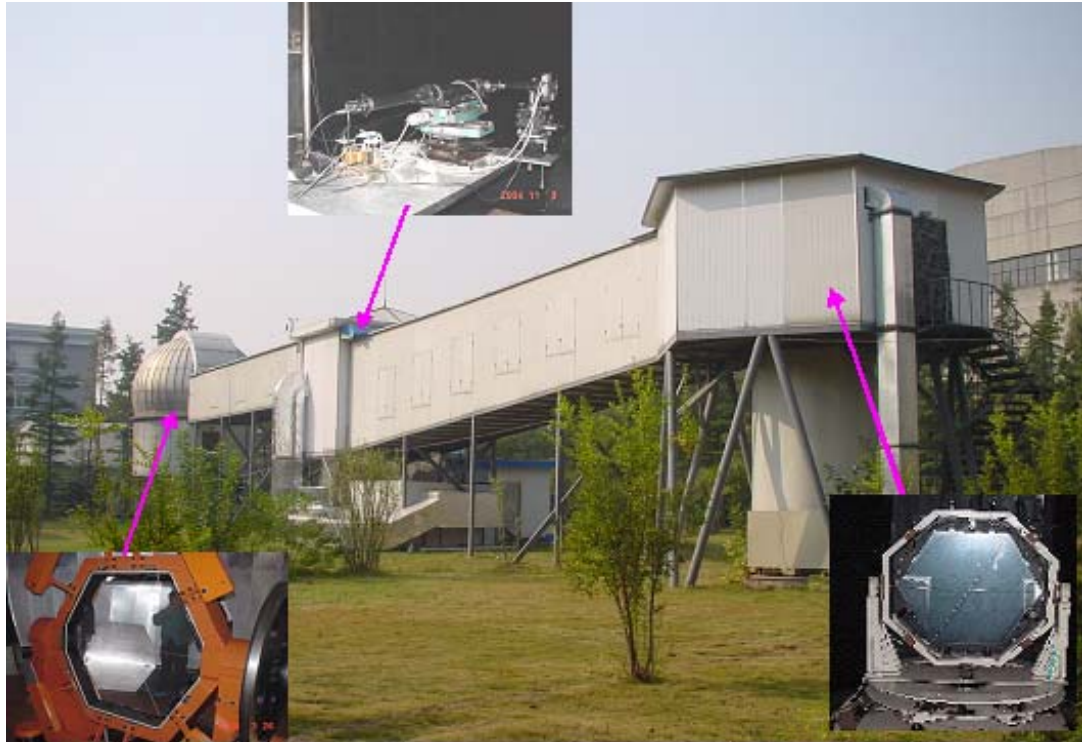
One of the M_B sub-mirrors polished by LZOS, Russia, of which glass blank was provided by Schott, Germany



One of the M_A sub-mirrors polished by Nanjing Institute of Astronomical Optics and Technology

Active Optics and Mirror Support System

For eliminating the spherical aberration of M_B , it is needed to change the shape of M_A during tracking. Combining thin mirror and segmented mirror active optics techniques, the required shape of M_A can be formed of 24 thin plane segments. Also the co-focus of 37 spherical segments can be reached by using segmented mirror active optics. This is the key technique and main innovation of the project.

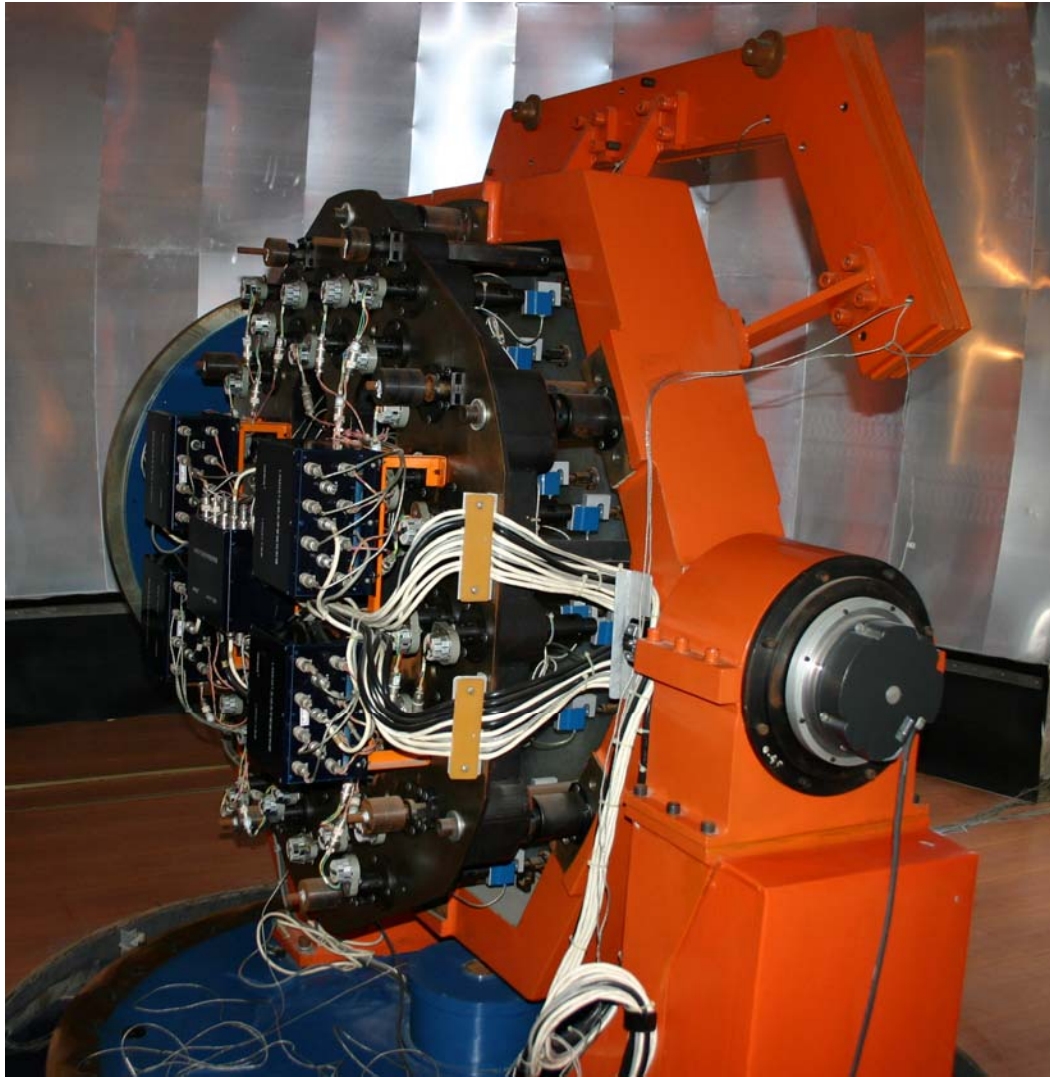


An outdoor experiment facility for active optics has been built on which a series of experiments were done related to the key technical innovation.

Thumbnails: Shark-Hartmann wave front sensor

M_A sub-mirror

M_B sub-mirror



The active supporting system of M_A sub-mirror

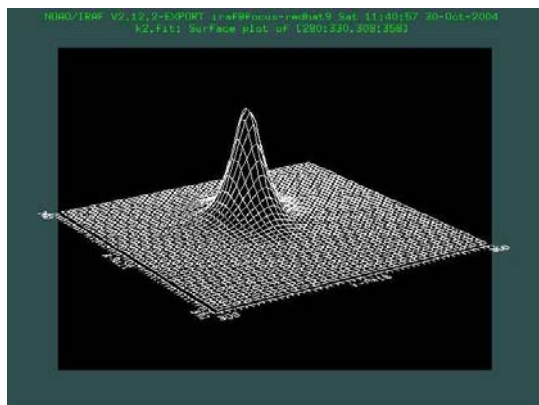
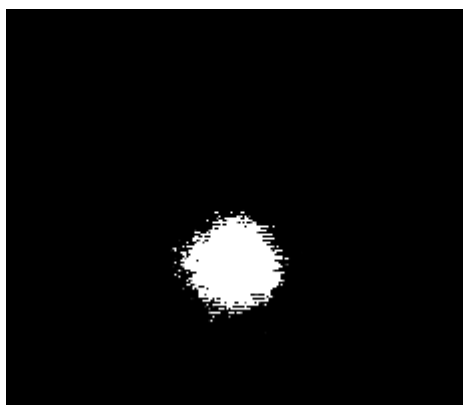
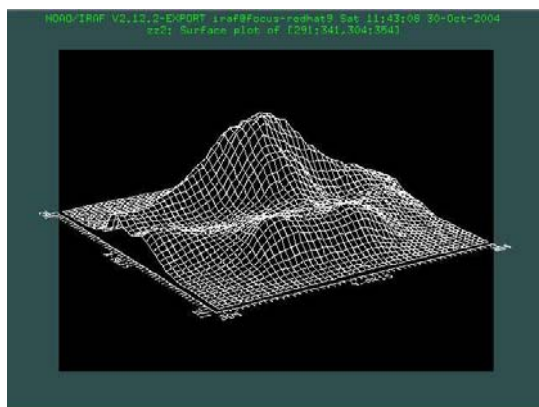
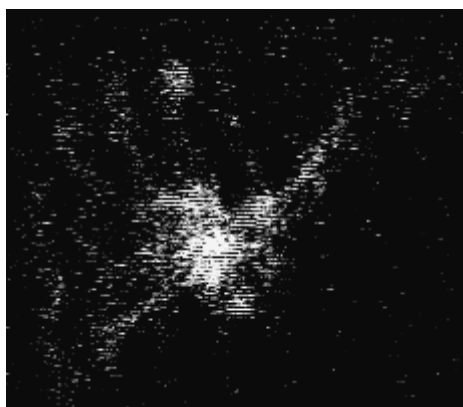
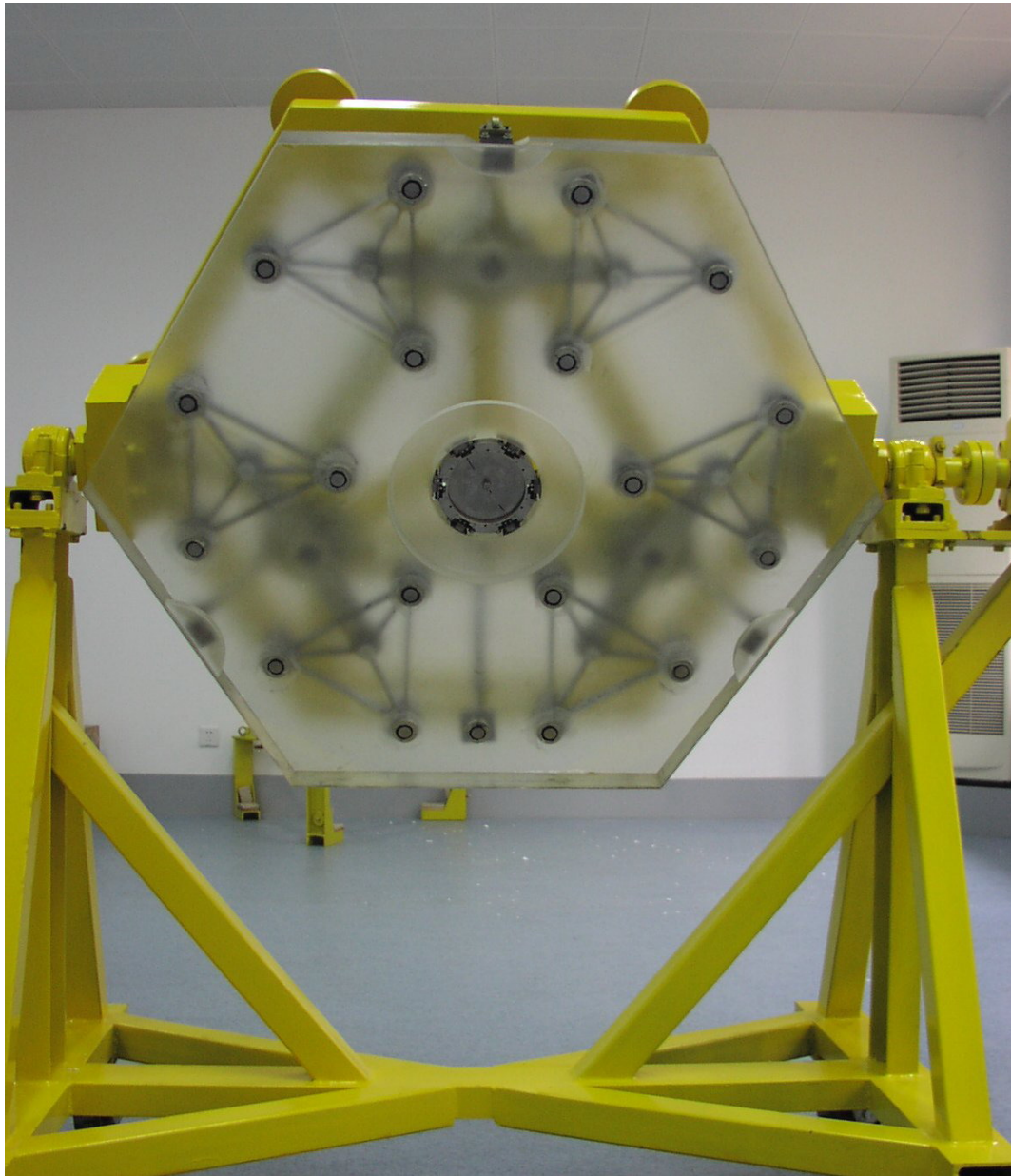


Image quality obtained before and after the active optics open-loop control corrections



Prototype of a M_A sub-mirror cell



Prototype of a M_B sub-mirror cell

Mounting and Tracking System

LAMOST is a meridian telescope with a fixed spherical mirror M_B , an alt-azimuth mounting reflecting Schmidt corrector M_A and a focal plane. The celestial objects are pointed and tracked by the movements of M_A . Observations are made mainly around the meridian. The required tracking speed is slow and its acceleration is small, without any blind spot. Hydrostatic bearing is adopted, direct friction drive is used for azimuth and altitude drive, and tape encoder is for precisely positioning. Focal plane rotates during tracking, so a de-rotating mechanism to compensate the field rotation is used. A focusing unit is also equipped in this system.



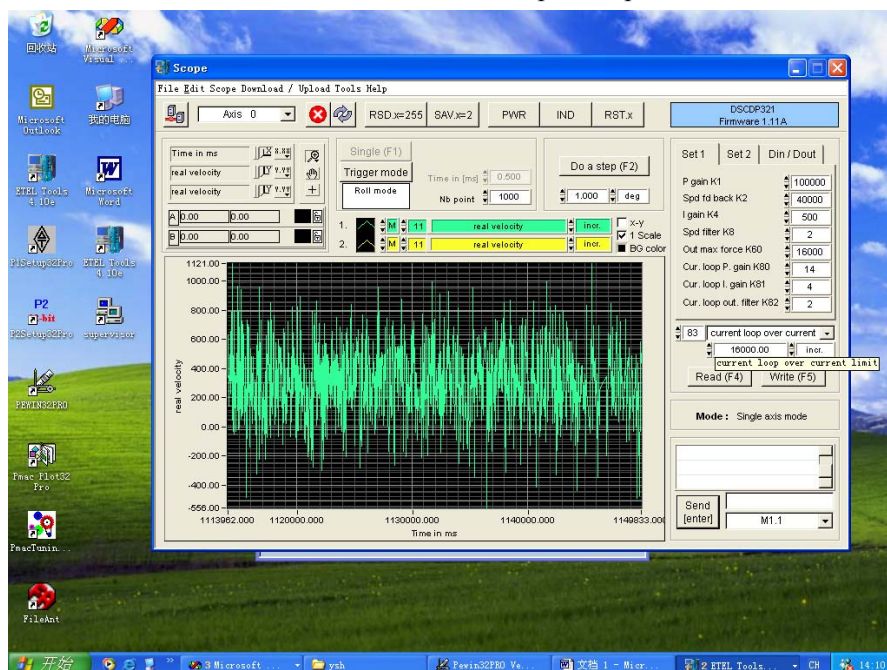
The M_A support structure in test, which is responsible for supporting the corrector mirror and the active optics system

Telescope Control System

Telescope control system consists of a ultra-low speed and high accuracy tracking system, a real-time control for about thousand of force actuators,an accurate and real-time fault-diagnosis and a real-time environmental inspection and alarming, etc. A number of cutting edge control theories and technologies will be adopted in the system, such as modern cybernetics, network transmission and communication, micro-electronics theory and technique, nanometer level driving, distributed data base, embedded control, disturbance prevention and diagnostic technique, simulation technique and object oriented programming, etc.



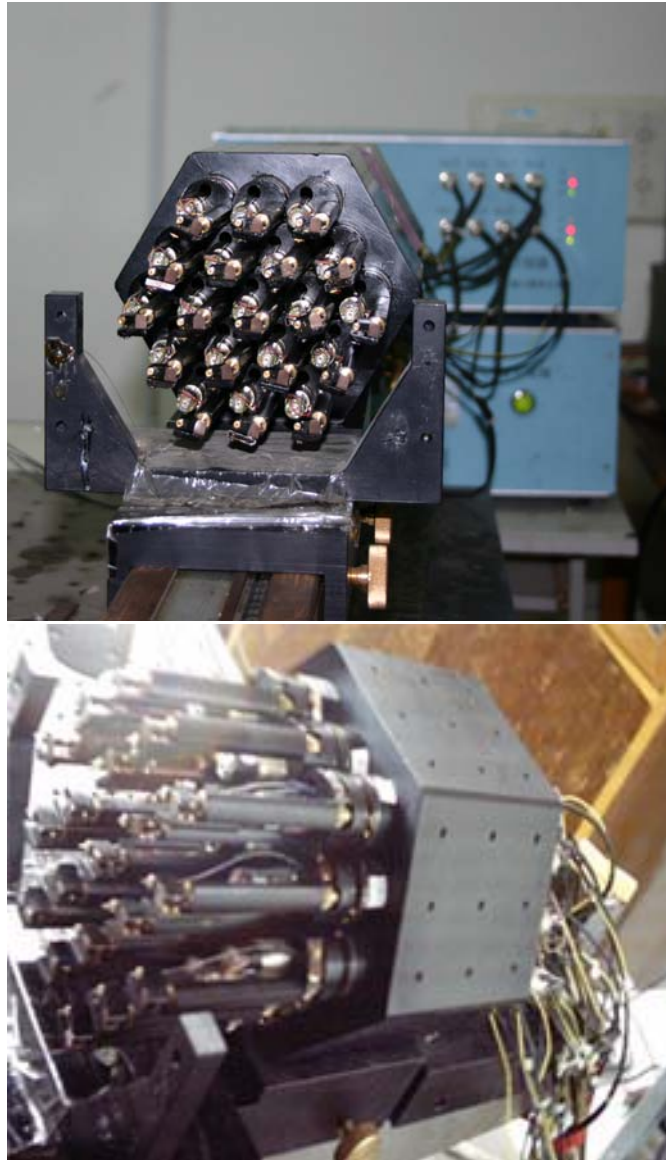
Controller of the active optics experiment



Stability curve of a mount motor in its free rotation

Focal Plane Instruments

The light collected is reflected from M_A to M_B then reflected by M_B and forms image of the observed sky on the focal plane. The light of individual objects is fed into the front ends of optical fibers accurately positioned on the focal plane, and then transferred into spectrographs fixed in the room underneath, to be dispersed into spectra and recorded on the CCD detectors, respectively and simultaneously.



The parallel controllable fiber positioning system promises simultaneously the movement of fibers in their own small regions and fine adjusting. The above picture shows the prototype of 19 fiber-positioning units.

The Low Resolution Spectrographs are optimized for galaxy redshift surveys. Every 250 optical fibers feed to one of the LRS. The $f/4$ output beams are collimated by a spherical mirror, and the collimated beams are split into red and blue parts by a dichroic filter. Through VPH gratings, spectra are focused onto large format CCD using an $f/1.25$ Schmidt camera. The spectral resolution $R=1000$, covering 370-590nm and 570-900nm respectively. The resolution can be

reached $R=2000$ by using a narrow slit, and it can be changed to $R=10000$ by turning to another grating.



Prototype of Low Resolution Spectrographs (LRS) for LAMOST

Telescope Enclosure

The enclosure is different from the traditional domes due to the novel layout of the telescope. The two upper parts of the M_A dome is removed during observation. The long tube encloses M_B and the focal plane units, with louvers on its sides. Its design is to lower the wind effect on mirror and to get good dome seeing.