Multi-Application Solar Telescope (MAST) at Udaipur Solar Observatory

Multi Application Solar Telescope (MAST) is a 50 cm aperture telescope installed at Udaipur Solar Observatory (USO) of PRL to study our daytime star, the Sun, at high-resolution. The telescope was built and installed by Advanced Mechanical and Optical Systems (AMOS), Belgium.

USO is situated on an island in the middle of the Lake Fatehsagar of Udaipur, Rajasthan, The sky conditions at Udaipur are quite favourable for solar observations. A large water body surrounding the telescope decreases the amount of heating of the surface layers. This decreases the turbulence in the air mass and thereby improves the image quality and seeing.

Main Components of the Telescope

- ❑ **Optical System**
- ❑ **Mechanical structure**
- ❑ **Thermal System**
- ❑ **Telescope Control System**

Auxiliary Components

- ❑ **Guider Telescope**
- ❑ **Wavefront Sensor**
- ❑ **M2 – Hexapod**
- ❑ **Field Stop**

OPTICAL SYSTEM

- Comprises of mirrors M1-M6 and DM1-DM3 (cf. Figure 2)
- M1 and M2 are off-axis parabolic mirrors, M3-M6, DM1-DM3 are plane mirrors
- M3-M5 forms Coude optics. DM1-DM3 forms derotator unit, compensates the field rotation
- M2-M5 are made of SiC-CVD, M1, M6, DM1-DM3 are made of Zerodur
- Mirrors are coated with protective silver coating, R_{avg} > 95% over 400 nm–900 nm. Average transmittance is 68% over 400-900 nm

MECHANICAL STRUCTURE

- Alt-azimuth mount
- Azimuth Range: 65° – 295° and altitude Range: 5°-88.5°.
- Comprises of Tube, Fork and Ground Interface Structure (GIS), Sunshield and Cable-wrap (cf. Figure 1)

THERMAL SYSTEM

Thermal system is designed to minimize the temperature difference between the ambient medium and the primary mirror (M1) so as to reduce the seeing effects. To achieve this,

- All the optical and mechanical components are cooled/heated to maintain the components at ± 1°C with respect to the ambient temperature.
- M1 front surface is flushed with compressed air at 1.5 m/s to minimize the mirror seeing.

TELESCOPE CONTROL SYSTEM (TCS)

- TCS helps in operation and control of the system. It interfaces with different components of the telescope and monitors its health.

Important Science Objectives of MAST: The primary goal of the MAST is to understand the evolution of the magnetic fields on the Sun and its relation to the solar activity. This is important as solar eruptions are responsible for extreme space weather conditions that pose threats to humans by disturbing the satellite communication, navigation etc., affect activities of humans in space and also the climate on the Earth.

In particular, MAST aims at observing the solar active regions (groups of sunspots) in high resolution by imaging them in two different layers of the solar atmosphere i.e. the photosphere and chromosphere. MAST is also aimed at measuring magnetic fields in these two layers.

Salient features :

- ❑ **50 cm clear aperture**
- ❑ **Off-axis Gregorian design**
- ❑ **Pointing accuracy < 10 arcsec**
- ❑ **Closed-loop tracking accuracy : ≤ 0.1 arcsec for 1 hour**
- ❑ **Active secondary mirror for telescope alignment while in operation**
- ❑ **Field-of-view : 3 arc-minute (1/10th of solar disk)**
- ❑ **Open (collapsible) dome**

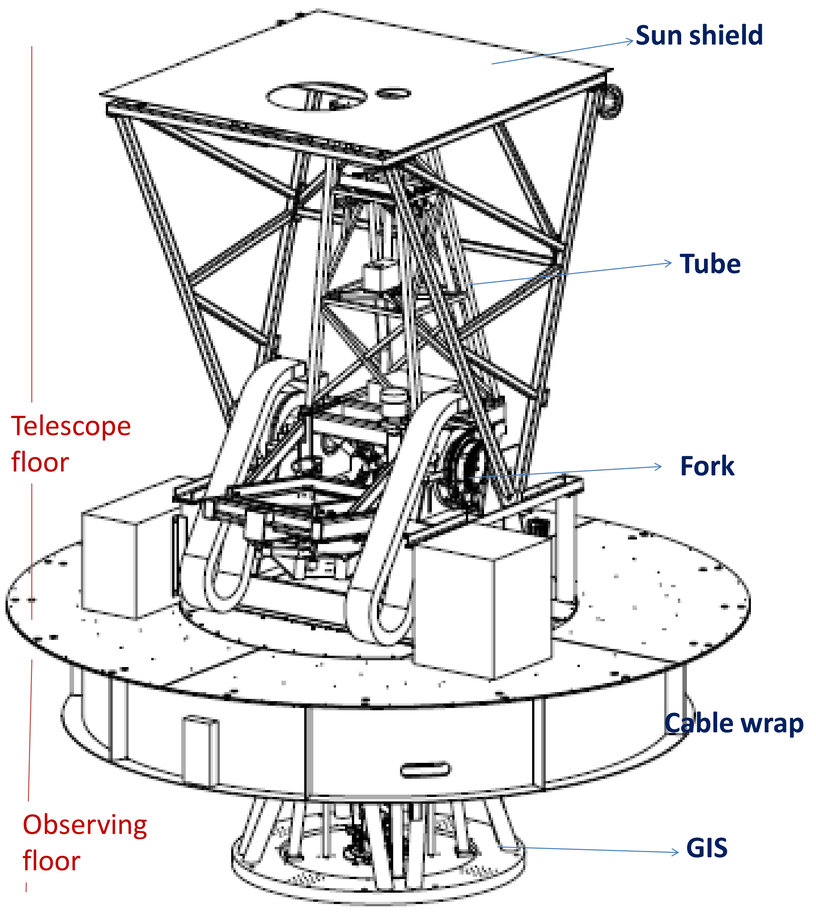

Figure 1. Mechanical Structure: *The structure runs into two floors, telescope floor (cf. Figure 3) and observing floor (cf. Figure 4). The sunshield, tube, and fork are seen on telescope floor and GIS and cable wrap are on the observing floor. Science instruments are placed on the observing floor.*

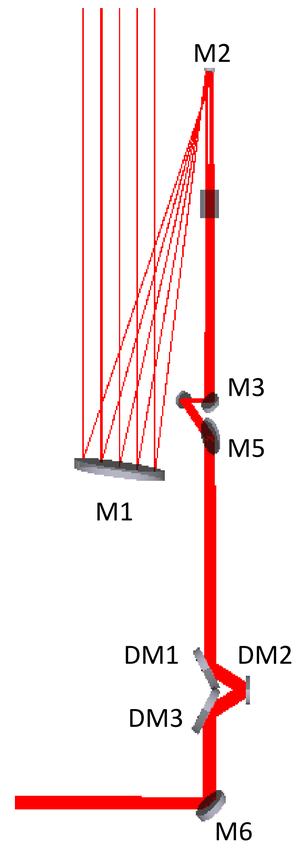

Figure 2. Optical Layout: *MAST is an off-axis Gregorian telescope. M1 and M2 are off-axis parabolic mirrors with an angular magnification of 10. Rest all are plane mirrors.*

❖ **Guider telescope**

- For compensation of tracking errors.
- F5.6 lens with 800 mm focal length.
- Plate-scale: 1.9 arcsec per pixel
- FOV : More than 3 times that of the Sun

Drive system specifications (Tracking accuracy)	
Pointing Accuracy	≤ 10 *arcsec*
Differential Pointing Accuracy	≤ 0.5 *arcsec*
Open-loop Tracking	≤ 0.25 *arcsec rms* over 10 min ≤ 0.05 *arcsec rms* for 1 s
Closed-Loop Tracking	≤ 0.1 *arcsec* for 1 hour

Figure 3. MAST is enclosed in a collapsible dome made of tensile fabric, built by Armatic Engineering, Bangalore. Top: Dome in closed condition, Bottom: Dome in open condition. Collapsible dome helps to athermalize the telescope surroundings.

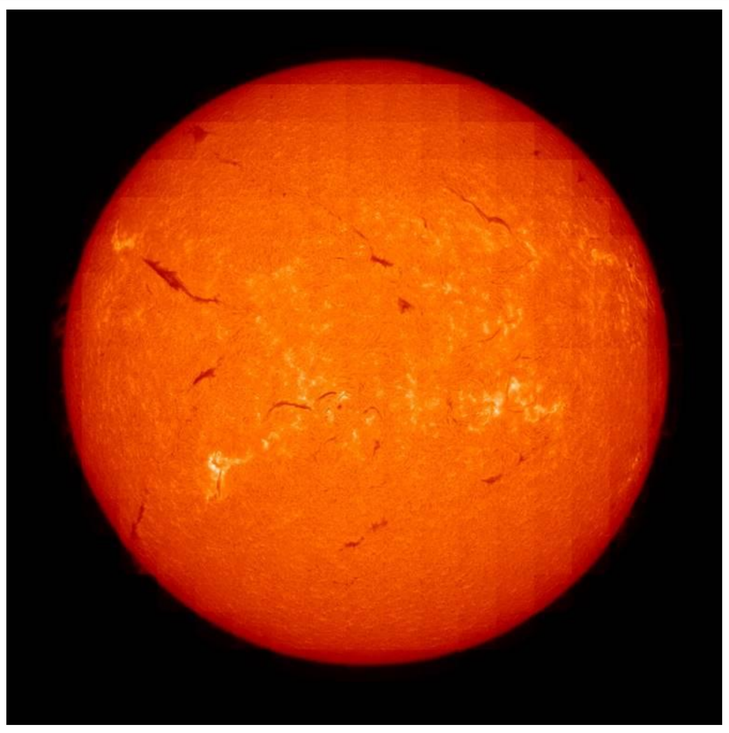

Figure 5: Hα full disk image constructed from a sequential mosaic of 293 images with 3 arcmin field-of-view taken by MAST on 19th May 2015.

SCIENCE INSTRUMENTS

Some of the fundamental questions that MAST is designed to address are:

- How are the sunspot magnetic fields formed and evolve?
- What are the magnetic field configurations that lead to flares and CMEs?

To answer these questions different instruments have been built in-house at USO and integrated with the telescope.

❑ **Imaging spectropolarimeter** for measurement of vector magnetic fields

- Observations in 6173 Å (Photosphere), 8542 Å (Chromosphere)
- Two Fabry-Perot etalons are used in tandem as narrowband filter (≈75mÅ)
- Polarimeter consists of two liquid crystal variable retarders (LCVRs) and a linear polarizer
- Measures Stokes vector, which will be used to obtain magnetic field parameters of the solar atmosphere.

❑ **Filtergraph** for simultaneous imaging of photosphere and chromosphere

- Broadband (≈ 10 Å) observations in 4305 Å (G-band)
- Narrowband in (≈ 0.5 Å) observations in 6563 Å (H-alpha)

❑ **Adaptive Optics** for compensation of atmospheric turbulence

- Shack-Hartmann Wavefront sensing
- 37 channel membrane mirror as wavefront corrector

❑ **Multi-slit spectropolarimeter (MSSP)** for vector magnetic fields

- Observations in 6302 Å
- *Echelle* grating, 23 lpmm, 122 order
- Spectral resolution: ≈ 40 mÅ

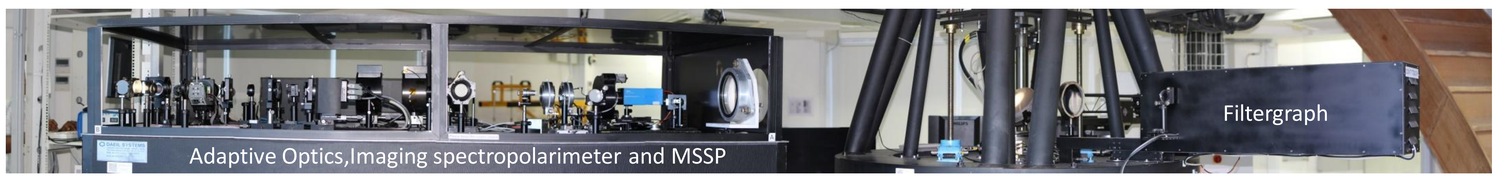

Figure 4. Mirror M6 of MAST can be rotated in four directions. Filtergraph, which is designed for simultaneous imaging in G-band and Hα is placed on the GIS along the East direction. Imaging spectropolarimeter and MSSP through Adaptive optics are placed on an optical table along the south direction.

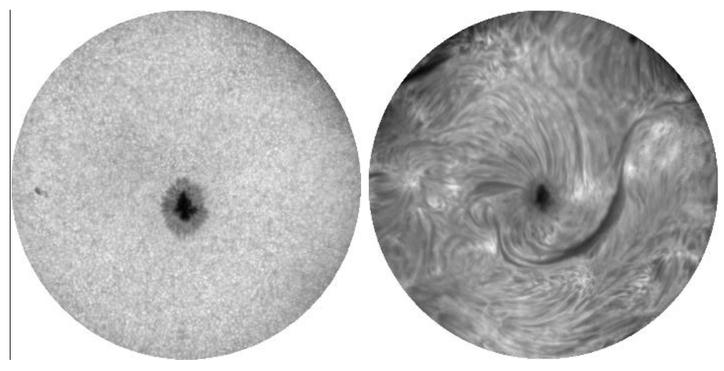

Figure 6: Intensity images obtained in G-band (left) and Hα (right) of an active region on Sun observed by MAST filtergraph. FOV is 3 arcmin.

MAST at USO promises to serve as an important ground-based facility and will complement the science objectives of the current and upcoming ground-based and space-based missions, by providing regular observations of the solar photosphere and chrmosphere.