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The European Solar Telescope

M. Collados[1], F. Bettonvil[2], L. Cavaller[3], I. Ermolli[4], B. Gelly[5], A. Pérez[1], H. Socas-Navarro[1], D. Soltau[6], R. Volkmer[1], and the EST Team

[1] Instituto de Astrofísica de Canarias, c/ Vía Láctea s/n, 38205 La Laguna, Tenerife, Spain e-mail: mcv@iac.es
[2] Sterrekundig Instituut Utrecht, Universiteit Utrecht, Princetonplein 5, 5384 CC Utrecht, The Netherlands
[3] GRANTECAN, S.A., c/ Vía Láctea s/n, 38205 La Laguna, Tenerife, Spain
[4] INAF, Osservatorio Astronomico di Roma, via Frascati 33, Monte Porzio Catone, Italy
[5] CNRS-UPS 853, c/ Vía Láctea s/n, 38205 La Laguna, Tenerife, Spain
[6] Kiepenheuer-Institut fr̈ Sonnenphysik, Schöneckstrasse 6, 79104 Freiburg, Germany

Abstract. The European Solar Telescope (EST) is a project to design, build and operate an European Solar 4-meter class telescope to be located in the Canary Islands, with the participation of institutions from fifteen European countries gathered around the consortium EAST (European Association for Solar Telescopes). The project main objective up to the present has been the development of the conceptual design study (DS) of a large aperture Solar Telescope. The study has demonstrated the scientific, technical and financial feasibility of EST. The DS has been possible thanks to the co-financing allocated specifically by the EU and the combined efforts of all the participant institutions. Different existing alternatives have been analysed for all telescope systems and subsystems, and decisions have been taken on the ones that are most compatible with the scientific goals and the technical strategies. The present status of some subsystems is reviewed in this paper.

Key words. Sun: telescopes – Sun: instrumentation – Sun: polarization – Sun: adaptive optics

1. Introduction

The European Solar Telescope (EST, Collados et al. 2010) represents the most ambitious project faced by the high-resolution solar physics European community. Aimed at starting its operation by the end of this decade or beginning of the next one, it will allow scientists to obtain the best images ever taken of the Sun with the best possible polarimetric performance. From a scientific point of view, its design has been driven by the requirement that the telescope must allow the users to observe simultaneously the solar photosphere and chromosphere by means of high-spatial resolution spectropolarimetry in the visible and near-infrared. Thus, EST will be optimized for studies of the magnetic coupling between the deep photosphere and upper chromosphere. The feasibility concerning key aspects needed for the conceptual design of the whole telescope, such as optomechanical design, cooling

Send offprint requests to: M. Collados mechanisms, adaptive optics, instrumentation and control system has been demonstrated.

The complementary performance of the instruments of EST will allow us to produce a three-dimensional view of regions of the solar atmosphere with unprecedented spatial, temporal, and spectral resolution. Imaging instruments have the capability to take the performance of the telescope to the limit and reach the diffraction limit of its optics. They will enable us to study details of the interaction between the plasma and the magnetic fields that are unresolved in current observations. Spectrometers moreover have the property that the full information along a spectral line is obtained, guaranteeing that the relevant physical information (temperature, velocity, magnetic field vector, etc.) may be retrieved. By using all these instruments together, the amount of information extracted from the observational data will be maximized. At present, no other solar telescope has, or plans to have, such a large amount of different and simultaneous instruments as planned for EST.

The various EST instruments will operate in particular wavelengths to provide adequate sampling of different layers of the solar atmosphere. With its instruments, one may say that EST will make it possible to observe the Sun in depth, to connect the physical processes that take place at different layers. EST will allow us to observe the Sun from the photosphere (where the properties of the magnetic field are governed by the plasma dynamics and thermodynamics) to the chromosphere (where, on the contrary, the plasma behaviour is governed by the magnetic field topology). Magnetic energy is stored below and in the photosphere, transported, and then released in the upper layers. EST will make it feasible to study all these interactions at the finest scales, where the fundamental processes take place.

Two main requirements are imposed on the technical design to achieve the ambitious goal of EST. On the one hand, EST will have a powerful multi-conjugate adaptive optics (MCAO) system like no other telescope has or will have in the near future. The atmosphere above the telescope distorts the incoming wavefront of the light, resulting in a deterioration of image quality. This degradation depends on the altitude of the turbulence, making it necessary to devise correction mechanisms for turbulence varying in height. At present, no common-use MCAO system exists at any solar or night-time telescope, although experiments to develop it are being carried out at different institutions. Correlation trackers started to be common at telescopes some twenty years ago, or even earlier. Nowadays, solar telescopes require adaptive optics to correct ground-layer turbulence effects. EST goes a step further and introduces in the optical path a complex, innovative and powerful set of deformable mirrors to correct for the effect of low and high altitude turbulence.

To maximize efficiency, the optical design of the telescope integrates in a natural way all the necessary active and adaptive optics, minimizing the number of optical surfaces. Efforts have been made to reach this goal to get two main advantages: on the one hand, the total throughput of the system and photon transmission is maximized; on the other hand, wavefront distortions introduced by the optical surfaces are kept to a minimum. A superb image quality will be one of the major strengths of EST.

In addition, the optical design of EST puts special emphasis on a polarimetrically compensated distribution of the optical elements. With this design, the polarization of the light as it comes from the Sun will be modified to a minimum extent. The interpretation of the solar data will thus be simpler and more accurate, without the parasitic polarimetric contamination introduced by oblique reflections on mirrors.

These two aspects (superb spatial resolution and accurate polarization measurements), solved in an innovative way, will make of EST a unique infrastructure in terms of performance.

Many other issues have been analysed, always keeping in mind the best optical and polarimetric behavior; e.g., thermal effects on the telescope environment, dynamic effects produced by the wind, deformations introduced by the varying gravity vector on the telescope structure, optimum reflective coatings to maximize the throughput and minimize the polarimetric impact, novel philosophies for polarimetric measurements, an effective light distribution system to maximize the light sent to the instruments, flexibility enabling the use combined or individual instruments taking into account particular scientific objectives, and a complex control system to handle all aspects of the data acquisition and on-site handling. The result of all these studies is an infrastructure which brings together the best of all existing solar telescopes, while incorporating new concepts to satisfy the future scientific needs of the European Solar Physics community during the coming decades.

The main characteristics of the system are briefly described below.

2. Baseline configuration

EST is a 4-meter class solar telescope with an on-axis Gregory configuration, aiming at superb spatial resolution and polarimetric performance. It will have a main instrumentation station at the Coudé focus with three types of instruments, each one composed of different channels to observe different wavelengths: broad-band imagers, narrow-band tunable filter spectropolarimeters and grating spectropolarimeters.

The telescope includes active and multi-conjugate adaptive optics integrated in the telescope optical path between the primary mirror and the instrument focal plane in order to maximize the telescope throughput and provide a corrected image at the Coudé focus for the three types of instruments simultaneously. The active optics system is composed of M1, M2 and different mirrors of the optical path. The adaptive optics system is composed of a fast tip-tilt mirror and a pupil deformable mirror (DM), and up to four DMs conjugated at different heights. The optical design is based on an aplanatic Gregory-type telescope with three magnification stages which finally yield an f/50 telecentric science focus. The design includes 14 reflections in total, arranged in pairs with incidence-reflection planes perpendicular to one another in order to compensate their instrumental polarization. This configuration allows the maximum number of capabilities: polarization compensation (Mueller matrix of the optical design near the unity matrix), integrated optical field de-rotation capabilities, telecentric design, collimated beam at AO system and four MCAO DM mirrors conjugated at different heights.

The telescope mechanical configuration is alt-azimuthal given that it allows a simpler and more compact system, with better primary mirror air flushing, making it possible to achieve a polarimetrically compensated optical design. The configuration of the telescope structure is determined by the optical layout. The elevation axis has been placed 1.5 m below the M1 vertex in order to facilitate M1 air flushing, also allowing space enough for the M1 cell and for an adequate placement of the transfer optics train vertically from the telescope to the Coudé focus where the instruments are placed. This unusual configuration of the elevation axis below M1 produces a large unbalanced weight around the elevation axis, which is compensated by the structure below M1. In addition, the azimuth and elevation axes are decentered with respect to the telescope optical axis because the optical path is folded in an asymmetric way to produce a polarimetrically compensated layout, with a telescope Mueller matrix that is nearly independent of the telescope elevation and azimuth angles, and for all wavelengths.

The instruments will be enclosed in the Coudé instrumentation laboratory in a controlled environment. Since each instrument is composed of several channels, the space required in the Coudé room is huge. To accommodate all the instrument channels, they are distributed on different floors. A configurable light distribution system composed of dichroics and beam-splitters will be placed at the Coudé focus in order to feed different instrument channels, making it feasible to have different ways of light distribution for simultaneous observations using a flexible number of instruments/channels.

The image rotation will be compensated at the Coudé focus in order to feed the instruments with a stable image. The proposed baseline to compensate the field rotation is based on an optical de-rotator integrated in the telescope optical path. The seven mirrors of the transfer optics between the telescope and the Coudé focus, including the MCAO DMs, are arranged in a way such that their input and output optical axes are coincident with the telescope optical axis. This arrangement allows this system of seven mirrors to work as an optical field derotator, rotating these mirrors around the optical axis at an appropriate rate. In addition, this design is also compensated under a polarimetric point of view, without introducing additional flat mirrors in the optical path. The arrangement of the transfer optics as a field derotator avoids the necessity to use a large rotating platform for the instrumentation, which is advantageous in terms of simplicity, instrument stability, cost and flexibility to allow future instrumentation upgrades. The alternative of providing a rotating instrument platform in the Coudé room to compensate the field rotation has also been studied, but was not preferred because of the limitations it implies for the instrumentation.

Given the alt-azimuthal configuration, a Nasmyth platform will be provided as an auxiliary focal station for a medium infrared or ultraviolet instrument that will be fed directly with telescope light without passing through the complete transfer optics. Fast tip-tilt and focus correction capabilities will be provided additionally to M2 in order to correct these effects at the Nasmyth focal station, which cannot take advantage of the correction of the AO system placed in the Coudé path.

The baseline telescope enclosure is completely foldable. This option has been selected since it maximizes natural wind flushing of the telescope, improving the local seeing conditions with less effort than with a conventional dome. An important advantage of the completely foldable enclosure is that it allows the use of a reflecting heat rejecter at the Gregory focus, while, with a conventional dome, it is necessary to absorb the heat inside the dome. The drawback of the open-air configuration is the higher wind effect on the image quality produced by wind shake on the telescope structure and wind buffeting deformation of the primary mirror. The wind effect has been taken into account from the beginning of the design, maximizing the stiffness of the telescope structure and primary mirror support, improving the bandwidth of the telescope drives, and providing fast tip-tilt and focus correction capabilities to the secondary mirror. The residual errors from wind effect can be corrected by the deformable mirrors of the AO system, although it is necessary to keep residual wind errors limited in order to avoid overloading the AO system. Additionally, a shield is proposed to reduce wind effects.

The telescope will be placed on the top of a tower to improve the local seeing conditions. The tower also supports the telescope enclosure. The Coudé instruments laboratory will be placed at the base of the tower. The transfer optics, including the MCAO system, will be distributed inside a chamber between the telescope and the instrument laboratory. The baseline for the telescope tower is a concrete tower that will enclose the instrument laboratory and the transfer optics, while providing the necessary stiffness to the telescope azimuth base. Since the instruments will be placed at the Coudé station at the base of the tower, it is important to minimize the tilt between the telescope and the Coudé focus and the lateral displacement.

A conical shape is proposed for the tower, in which the upper concrete part has a reduced diameter. The enclosure is supported with a transparent framework structure, to reduce the air obstruction and the turbulence at the telescope area. The optical layout is arranged on a tower height of, approximately, 33-38m between the base of the Coudé laboratory and the telescope platform, which is adequate for reducing the ground layer effect on the local seeing conditions.

A building containing the required control and support installations and facilities will be attached to the tower, providing access to the telescope pier. An additional auxiliary building containing the facilities which might otherwise degrade the telescope performance (due to vibration or air heating produced by the power plant, pumps, water coolers, etc.) will be placed far enough from the telescope tower in order to have no impact on local seeing.

The EST facilities will include an auxiliary full disc telescope that will be used to give the observer a global context of the solar activity and for precise coordinate measurements (Sobotka et al. 2010).

3. Optical design

The EST optical design will form an image of the Sun at its Science Coudé Focus providing the scientific instrumentation with an object plane (Sanchez-Capuchino et al. 2010).

The design of the optical system of EST is constrained mainly by the science requirements. However, there are also some fundamental requirements that drive the design:

1. EST must have an entrance-pupil equivalent to a circular aperture of diameter 4 metres. With this, it will provide a significantly improved angular resolution over what is achievable with the current 1-metre class telescopes. The increase in resolution will allow reaching the small spatial scales required to study the solar magnetic phenomena.
2. EST must cancel the instrumental polarization introduced by the telescope. This entails the polarization of the incoming light not being modified, independently of the pointing of the telescope to any direction on the sky. This property must hold for all wavelengths.
3. EST must provide excellent image quality, limited by diffraction over a circular FoV of 1 arcmin in diameter through a wavelength range from 0.39 μm to 2.3 μm. The system must be seeing-limited in an unvignetted FoV of 2×2 arcmin^2.
4. EST must have high-order AO and MCAO systems integrated into the main telescope light path to provide the highest possible spatial resolution.
5. EST must be optimized to give a high throughput, being composed of a minimum number of optical surfaces.
6. The Science instruments of EST have to operate simultaneously to maximize operational efficiency.

The optical design of EST can be divided into three main subsystems (see Fig. 1), where each one has a relative movement with respect to the others:

1. The first is the main telescope (M1 and M2) defined by an on-axis Gregory configuration.
2. The second is the main axes subsystem (M3 to M8) and integrates those mirrors that define the elevation and azimuth axes. This subsystem houses an on-axis magnification stage (M5) to produce the pupil used by the AO system.
3. The third is the transfer optics subsystem (M9 to M14) whose mirrors transfer the light from the main axes subsystem to the Science Coudé Focus. In addition, this assembly integrates the MCAO mirrors inside its light path and also works as the field de-rotator of the telescope. This subsystem houses two off-axis magnification stages (M9 and M13) to get an adequate f-ratio at the MCAO post-focus DMs and the Science Coudé Focus.

3.1. Main telescope subsystem

The on-axis Gregory main telescope integrates an f/1.5 primary mirror (M1) and a secondary (M2), defined as the aperture stop of the whole system, which gives an f/11.8 Gregorian Focus (F2). A heat rejecter that also works as a field-stop is located at the primary focus (F1) to limit the field of view to the required unvignetted 2×2 arcmin^2.

The entrance pupil of the system, which has a diameter of 4070 mm, is defined by the conjugation of the aperture stop (M2) (whose diameter is limited to 800 mm) through M1, with 4100 mm in diameter. The inner central circular obscuration, typical of a Gregory-type aperture stop, has been increased in the EST optical design from 148mm to 260 mm in diameter, the reason being the necessity of providing a reasonable envelope for the heat rejecter. M2 will be mounted on a hexapod, with 5 degrees of freedom (piston, δx, δy and slow tip-tilt) to perform active optics tasks. Besides, M2 could be used as a fast AO tip-tilt mirror,

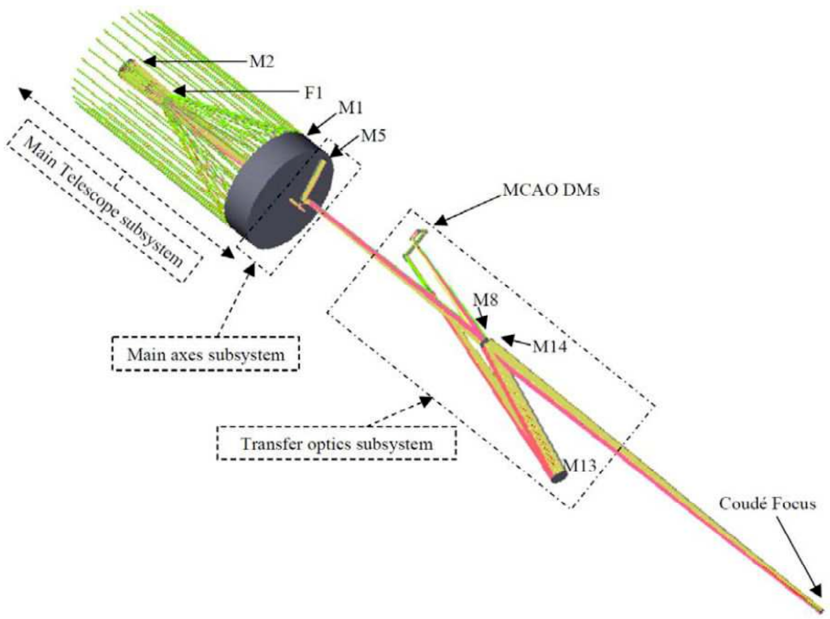

Fig. 1. Optical layout of EST showing the three optical subsystems: main telescope, main axes and transfer optics.

with a limited bandwidth. If a larger bandwidth is required, a second smaller and faster tip-tilt mirror, M6 (which is located in the main axes subsystem), will be used. Including fast tip-tilt and piston capabilities for M2 would provide an adaptive correction for the Nasmyth station.

The fulfilment of the envelope diameter (225 mm) for the heat rejecter leads to an M1 hole increased by 290 mm with respect to the M2 diameter, giving an inner hole of 677 mm in radius.

The telescope elevation axis is located 1.5 meters below the primary mirror vertex and the azimuth and elevation axes are decentered with respect to the optical axis of the main telescope because the optical path is folded in an asymmetric way to produce a polarimetrically compensated performance, with a telescope Mueller matrix that is independent of the telescope elevation and azimuth angles, for all wavelengths (Bettonvil et al. 2010, 2011).

3.2. Main axes subsystem

For the purpose of analysing the polarimetric performance of the rest of the telescope, a truly polarization-free focus just before M3 is foreseen. Only the rotationally symmetric M1 and M2 and its spider, which is also symmetric, will be located in front of it. Here, a polarization calibration unit will be located. After the polarization unit, the elevation axis is defined by the flat mirrors M3 and M4. Both are tilted 45 degrees in perpendicular planes to auto-balance their instrumental polarization provided their reflection coatings have the same properties. This is the philosophy applied to the whole design in order to cancel the instrumental polarization introduced by the telescope.

In the main axes subsystem, the ground-layer turbulence correction is also accomplished. The on-axis parabolic collimator mirror M5 generates a pupil in M7 (pupil DM) through a nearby flat M6 which, if necessary, will have pupil fast tip-tilt correction capabilities.

3.3. Transfer optics subsystem

The MCAO stage has been integrated in the transfer optics, after the main axes subsystem, in order to keep the pupil well stabilized. Nineteen meters further on from the main axes subsystem, the transfer optics subsystem has a tilted 2-meter off-axis ellipsoid (M8) allowing the post-focus location of the four MCAO DMs (M9, M10, M11 and M12 respectively). The exact conjugated heights and the number of mirrors may change depending on future MCAO studies and turbulence measurements at the Canarian observatories. The current MCAO assembly has its mirrors tilted 45 degrees in perpendicular planes to keep the instrumental light polarization invariable. One of the advantages of this design is that the exact tuning with height of the DMs does not have any impact on the optical concept of the telescope.

The second magnification stage of the transfer optics includes a tilted off-axis ellipsoid (M13) that conjugates the MCAO focus into the f/50 Science Coudé focus through the flat M14. This is assembled to send the Coudé focus light downward in the same direction as the light path that goes to M8 in order to provide field de-rotation capabilities.

Figure 2 shows the MTF diagram in F4 for the diffraction-limited FoV of 1 arcmin where the effects of the EST annular pupil have been taken into account. The central obscuration of the aperture stop, which in EST covers 11.14% of the total area of M1, degrades the image in F4 causing a reduction in the Strehl ratio and a decrease in mid-spatial frequencies in the MTF. The annular pupil gives rise to larger values of the MTF at high frequencies (between 30 mm^{-1} and 40 mm^{-1}) but lower values at low frequencies (below 30 mm^{-1}), compared to the MTF for the corresponding circular unobscured pupil.

4. Adaptive optics

The ground-layer adaptive optics (GLAO) is composed of the pupil DM and the tip-tilt mirror. According to the optical design, the pupil DM is M7 which is located at a pupil position. The optimum subaperture size that has been obtained, after a trade-off analysis between resolution (larger apertures) and degrees of freedom (smaller apertures), is 8 cm, corresponding to 50 subapertures across the pupil mirror, which means 51 actuators across the DM diameter. According to the optical design, the actuator pitch will be 5 mm in one axis and 3.6 mm in the other axis, which are feasible values for conventional piezoelectric-actuator deformable mirrors (e.g. CILAS or Xinetics). The stroke required for the DM actuators is, approximately, 12 m peak-to-valley, which is also a feasible value for conventional piezoelectric mirrors with the required pitch. Approximately, 50% of this stroke will be dedicated to compensating for atmospheric effects and 50% to telescope effects. This value of the stroke includes the extra stroke required due to the placement of the DM at 45 with respect to the optical beam.

The tip-tilt mirror can be implemented at M2 or at M6 (or at both positions, if two tip-tilt mirrors are considered). M2 defines the telescope pupil and will include fast tip-tilt and focus capabilities in order to provide some wavefront correction to the Nasmyth focus, which cannot take advantage of the AO system correction. M2 fast tip-tilt and focus correction capabilities will compensate for a large fraction of the wavefront distortions produced by the deformation of M1 induced by wind buffeting in open air conditions, since it makes feasible the correction for piston and focus errors, in addition to the tip-tilt components. These capabilies are also useful for the Coudé path, since fast capabilities of M2 can reduce the load on the rest of the AO system. Due to the large size of M2 (800 mm in diameter), the correction bandwidth of this mirror will be limited.

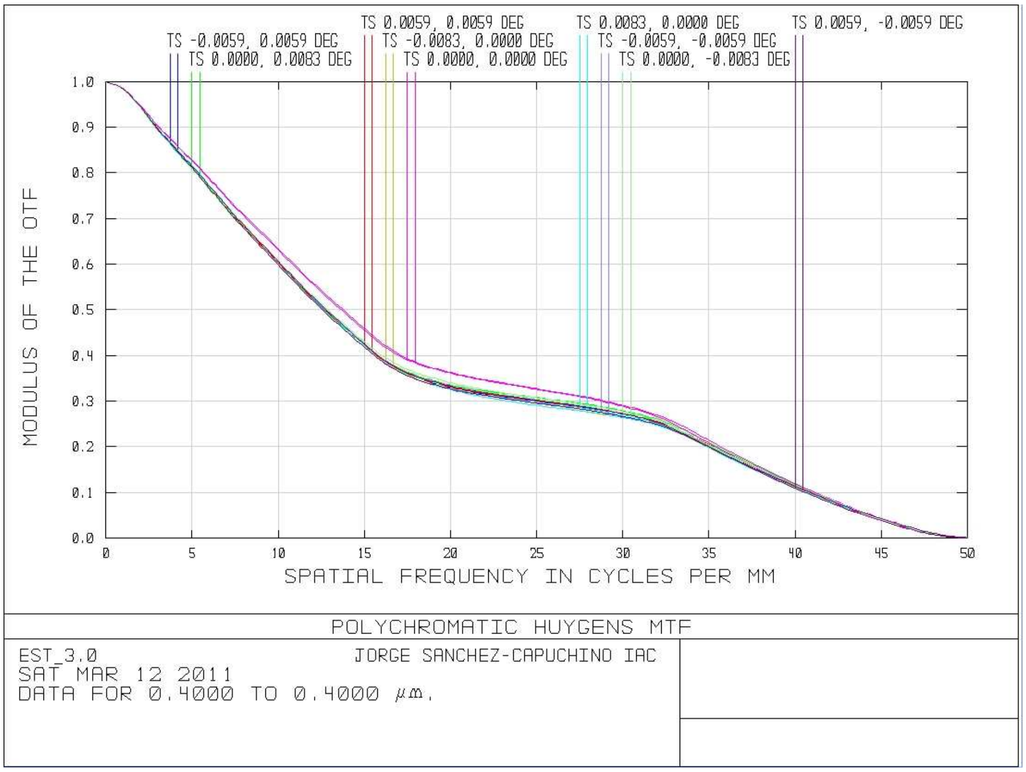

Fig. 2. MTF diagram in the Science Coudé focus F4 for the diffraction-limited FoV of 1 arcmin.

Consequently, the possibility to implement a second smaller and faster tip-tilt mirror at M6 has been foreseen. M6 is located at, approximately, 700 mm from the pupil M7, hence it is close enough to the pupil position to be used as a tip-tilt mirror. Should a sufficient bandwidth be achieved with M2, this mirror will be used as the main AO tip-tilt mirror, avoiding the implementation of an active M6.

4.1. MCAO

The MCAO optical design (and especially the number and size of the conjugate high altitude DMs) depends on the turbulence stratification with height above the telescope site. An obstacle lies in the large zenith angles (in the morning) that are typical for solar observations, leading to effective turbulence heights varying over a wide range. The proposed configuration is based on four conjugated DMs (M9-M12) at fixed positions, in order to reduce the height mismatch between the DMs and the turbulence layers caused by a zenith angle varying during the day. The position of the conjugate DMs were initially fixed at 5, 9, 15 and 30 km for the optical design, being optimized during the design study (Berkefeld et al. 2010; Soltau et al. 2010). The optimal positions obtained are 1, 3, 13 and 25 km. The spatial sampling assumed on the pupil is 10, 17, 34 and 56 cm respectively, corresponding to a mirror actuator pitch of 3 mm in one axis and 4.2 mm in the other axis for all the mirrors.

The MCAO conjugated mirrors can be bypassed by flattening them whenever the MCAO is not used. Since the MCAO will only correct a partial region of the FoV of the telescope, and to make their operation compatible with a FoV of 2’x2’, the DMs must be manufactured with a deformable central area with a diameter of

1.4 arcmin (1'x1'), the outer part of the mirror being non-deformable and flat.

Due to the proposed design of the transfer optics system as a de-rotator, a relative rotation will be produced between the pupil DM and the MCAO DMs during telescope operation. The effect of the differential rotation on the MCAO performance has been analysed and considered minor if each DM keeps the orientation of its actuator pattern with respect to the respective WFS.

4.2. Active optics

Considering the size of the telescope and primary mirror, the telescope must include active optics in order to keep the alignment and optical figure of the mirror compensating for initial alignment tolerances, changes in the gravity vector with elevation angle, temperature variations or wind buffeting. Continuous operation of the active optics system will be needed throughout the telescope operation in order to guarantee the optical quality of the telescope, and also when the adaptive optics is not operated.

At the first stage, the image motion generated by predictable low frequency perturbations will be controlled by the telescope guiding or the M6 tip-tilt mirror, with a range up to few arcsec. However, unexpected perturbations and residuals of medium frequency should be corrected in closed-loop by a second stage. These medium frequency residuals cannot be controlled by the guiding system and the M2 tip-tilt mirror could be in charge of this correction. This correction would penalize the image quality, though, by increasing the coma of the image, and corrections in the range ± 3 arcsec, approximately, are allowed to fulfil the image quality requirement. The final stage of corrections, where the higher frequencies are compensated, is definitely accomplished by the DMs of the AO system.

4.3. Wavefront sensing

The proposed WFS is a Shack-Hartmann sensor, well known in solar telescopes. It allows operation down to r_0 = 6 cm, tracking on granulation at λ = 500 nm. The main drawback of this sensor is the large number of pixels required for the WFS camera and the high computational power required. A completely new sensor, based on a CAFADIS camera, where microlens arrays are placed in the image plane instead of the pupil plane, is also being investigated, although the baseline for EST is Shack-Hartmann since there is no practical experience using CAFADIS cameras in adaptive optics.

5. Polarimetry

Precise and sensitive polarimetry forms a cornerstone for EST. For this reason, the polarimetric characteristics have been analysed from the very beginning during the conceptual design process, both in terms of the optical design (with its Adaptive Optics and Multi-Conjugate Adaptive Optics systems), the location of the calibrators and modulators, as well as calibration strategies and the choice of coatings and detector types.

The Science requirements for EST list specifications for both the polarimetric sensitivity and accuracy. The polarimetric sensitivity of EST should be 3×10^{-5} S/I, where S is any Stokes parameter.

Other requirements that have been defined are:

1. the system shall deliver polarization modulation for all polarimetric instruments (it has to be decided whether the modulation is performed in the main optical train or at instrument level);
2. functionalities for polarimetric calibration of the whole optical system should be included (in principle the polarimetric calibration assembly shall be located before any folding mirror);
3. the polarization optics will be integrated in the optical path and should be removable;

Just after the axis-symmetric mirrors M1 and M2, close to the instrumental polarization-free secondary focus F2, space is reserved for calibration optics and modulators, which can be slid in and out of the beam. Modulators can be of any type, optimized, for example, for efficiency or wavelength coverage, a polychromatic type with switching capabilities being one option. The complete optics train up to the science focus, including both elevation and azimuth mirrors, and the AO and MCAO system, is polarimetrically compensated. After the science focus, all optical elements are statically aligned, with the s- and p- planes being the eigenvectors of the total system after the science focus. The analysers are placed at each instrument and send the light as dual beam to the demodulating detectors. A second modulator can be located also at instrument level, as well as extra calibration optics and/or polarimetric compensators. The great advantage in also locating polarimeter components at each instrument is flexibility.

6. Instruments

The instruments are distributed in the Coudé room in two floors, the upper one dedicated to imagers and the lower one to grating spectrographs. The instrument layout takes into account the current design of each instrument type (number of channels-volumes-entrance focus position-optical axis height-spectral range) and the possibility of adding 2 additional guest instruments (one in the visible beam and one in the NIR beam). The light distribution system includes all mvoing parts (with exchangeable beamsplitters/dichroics/mirrors/compensators needed to achieve flexible combinations) and the electronic cabinets for the instruments and light distribution mechanisms.

The instrument layout has been designed for two cases: with the instruments static on a concrete slab (field rotation being provided by transfer optics) and with the instruments installed on a rotating platform (for alignment purposes and to compensate for image rotation). The former was found to be preferred, since it minimizes the number of elements to be rotated, giving more flexibility to the instruments design and for future developments and upgrades.

The light coming from the telescope is shared among the following instruments channels:

- 3 visible broad band imager channels (Munari et al. 2010),
- 5 narrow band imager channels: 3 operating in visible wavelengths and 2 in the near-infrared,
- 4 grating spectrographs: 2 for the visible spectral range and 2 for the NIR. These spectrographs are versatile and can operate in different configurations, using adequate additional modules. There are four possible configurations (Calcines et al. 2010):
  - Long-slit Standard Spectrograph (LsSS),
  - Multi-Slit Multi Wavelength SPectrograph equipped with an integral Field Unit (Calcines et al. 2011),
  - Tunable Universal Narrow band Imaging Spectrograph (TUNIS),
  - Multi-channel Subtractive Double Pass, New Generation (MSDP-NG) .

The light distribution among the instruments (see Fig. 3) is based on a division of the main beam coming from the transfer optics by a main dichroic D1 in two spectral stations: one for visible wavelengths and another for near-infrared. This division makes it possible to optimize the light flux transmission (after the beam separation, coating optics can be optimized for the selected spectral range at each station).

After BS5, the transmitted beam goes to the scanning unit of the two NIR spectrographs (a single unit for both). This unit is based on a quad-mirror (i.e. two pairs of 45°-incidence mirrors, for which the lines that connect the centre of the mirrors of each pair are perpendicular to each other). By moving the first pair of mirrors in a direction parallel to the line that joins them, the image is displaced in that direction. The same can be applied to the second pair of mirrors. This way, the FoV of the telescope can be scanned in both directions to select the adequate FoV for the spectrograph without affecting the imaging instruments. For the visible branch, one similar quad-mirror is

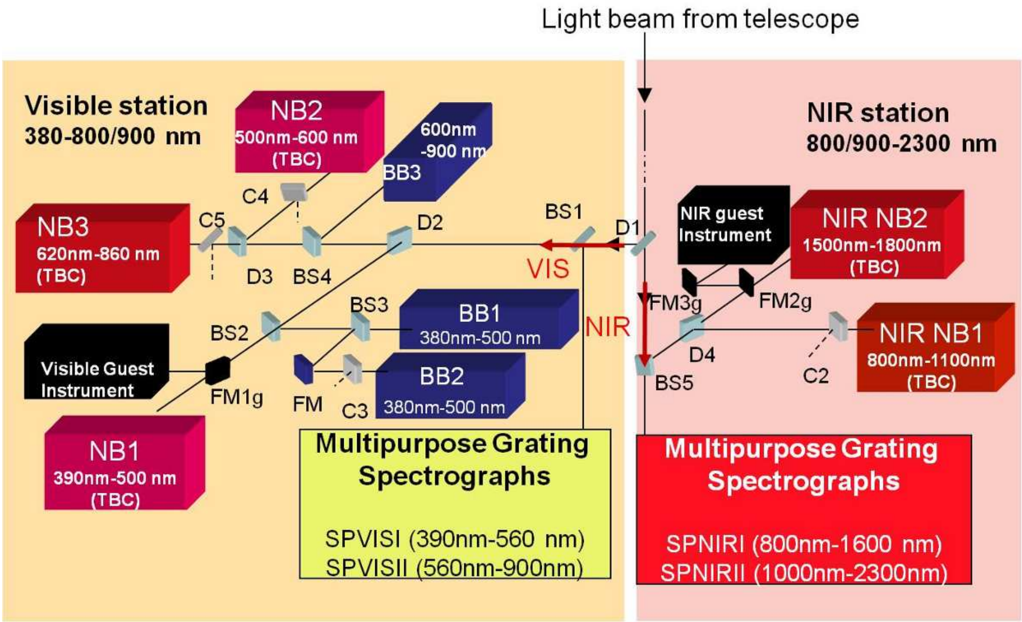

Fig. 3. Light distribution system for the instruments of EST.

located in the beam reflected by BS1 to scan the entrance FoV of the visible spectrographs. In addition, these quad-mirror scanning systems can also focus the image at the entrance focal plane of the spectrographs.

7. Conclusions

The main characteristics of the different subsystems composing EST have been presented. They all aim at getting a versatile facility which maximizes the photon and polarimetric detection efficiency by minimizing the impact of instrumental polarization on the data and by sending the maximum possible amount of light to the instruments with a flexible light distribution system. The telescope is also designed to minimize the image degradation to make it possible to obtain the highest quality data of the Sun at photospheric and chromospheric levels.

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