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A Broad Band Imager for the European Solar Telescope

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Abstract. The European Solar Telescope (EST) is a joint project of several European research institutes to design and realize a 4-m class solar telescope. The EST Broad Band Imager is one of the baseline instruments of EST. It will obtain diffraction limited images over the full field of view of EST at multiple wavelengths and high frame rate. Its scientific objectives are the study of fundamental astrophysical processes at their intrinsic scales in the Sun's atmosphere. Here we report on the current optical design of the instrument.

Key words. Solar telescopes – Optical design – Instrumentation

1. Introduction

EST (European Solar Telescope) will be a 4m class solar telescope. It will have a Gregorian on-axis optical configuration and an alt-azimuthal mounting and it will be installed at the Canary Islands, on the top of a 30m tower, so to improve the local seeing conditions. A multi-conjugate adaptive optics system and a derotation system will be integrated in the transfer optics between the telescope focus and a F/50 science focus in a two floor Coudé room, where three types of instruments, each composed of different spectral channels, will be installed: a Broad-Band Imager (BBI), a Narrow-Band Tunable Spectropolarimeter and a Grating Spectropolarimeter. Light coming from EST will be sent to the instruments following a light distribution scheme similar to that shown in Figure 1. The main characteristics of EST are summarized in Table 1.

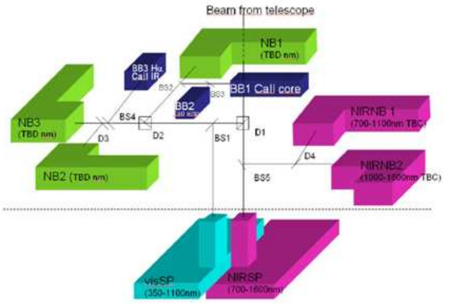

Fig. 1. Light distribution among instruments from Cavaller et al. (2010)

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Table 1. EST Main caracteristics

Entrance pupil diameter	4000mm
Field of view	2'x2' (goal 3'x3')
	1'x1' Diffraction Limited
F-Ratio at science focus	50
Plate scale at science focus	1"/mm
Number of reflections	10-16*

*depending on the selected configuration

2. BBI: The Broad Band Imager for EST

2.1. Requirements

The Broad Band Imager (BBI) will be one of the baseline instruments for the European Solar Telescope. It will be involved, alone or in conjunction with other EST instruments, in several scientific programs (see Collados et al. (2008) and Socas Navarro et al. (2010)). It will exploit both the high resolution and the large field of view delivered by EST. For such goal a multichannel and multispectral instrument has been designed. From requirements (see Table 2) the BBI will have at least 3 spectral channels working simultaneously. The spectral range will be from below 390nm to 900nm. There will be two operational modes(see Table 3): the first, the high resolution mode, will cover a 1'x1' field of view (FoV) taking advantage of the corrected FoV of the adaptive optics system of EST; the second, the maximum field of view mode, will cover the total 2'x2' FoV of the telescope.

In addition to these requirements, some other constraints have been considered in the design:

- The 'standard' detector for the BBI will be a 4k x 4k pixels, 10 micron pixel size.
- Each channel of the BBI should occupy a total space envelope of no more than 1x1x5 m.
- Each channel should be thought as a 'stand alone' instrument, i.e., the different channels should not share elements.
- The request to obtain quasi-diffraction limited images requires to foresee an instrument that use post-facto reconstruction techniques, e.g. MOMFBD (see Van Noort et al. (2005)); for such a goal, for every channel three focal planes (and detectors) are foreseen: two for phase diversity technique for the chromospheric lines, one for a 'companion' continuum line that can be used to correct the data of the chromospheric line; so each channel should foresee 3 subchannels, that should share as much as possible optical elements (to reduce differences in aberrations).
- The necessity of three subchannel implies a back focal distance large enough to place filters and splitters. We estimated that in 500mm.

Finally, the BBI will be equipped with the filters listed in Table 4, distributed among the channels.

2.2. Design

As said, the BBI will be a multichannel instrument. There will be two arms: a Blue one (390-500nm), split in two channels, and a Red one (600-900nm), with one channel only. The light coming from the telescope will be distributed to the channels with the use of dichroics and beam-splitters, so that the simultaneous use of all the channels will be possible. At the moment, the optical design of the three channels is a common one: a system composed by three couples of doublets and some plane mirrors to realize the two operational modes (see figure 2). Once split in channels by the dichroics/splitters, the light passes through a first doublet, common to both the observa-

Table 2. BBI Requirements

Number of spectral channels	3 channels working simultaneously (goal 5)
Observation modes	Optimum spatial resolution, Maximum field of view
Maximum Field of View	2'x2'
Angular Resolution	0.04" @ 500 nm (goal of 0.03"), Optimum on a 60"x60" Field of View
Mosaic Mode	3'x3' mosaic mode at optimal resolution (60"x60" patches)
Wavelength Coverage	From 390 nm to 900 nm
Wavelength Switching	< 2 seconds
Maximum bandpass shift	5x10-3nm (goal 3x10-3) @ 500nm, 30" from the field center
Transmission	Total throughput > 30%
Telecentricity	At the detector

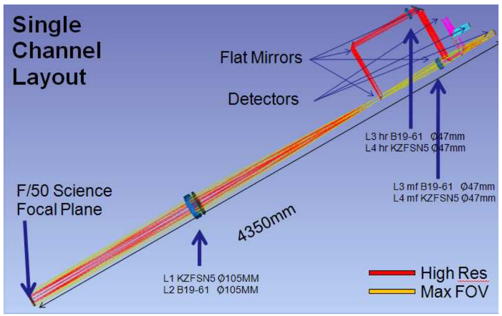

Fig. 2. Single channel Layout

Table 3. Observational Modes Data

	High Resolution	Maximum FoV
Detector Format	4k x 4k	4k x 4k
Pixel Size	10 micron	10 micron
Sampling	0.016"/pix	0.03"/pix
Field of View	64" x 64"	2' x 2'
Scale	1.6"/mm	3"/mm
F-Ratio	32	17

tional modes. After that, the beam can go on straight through a second doublet, forming the 'Maximum Field of View Mode' focus on the detector, or a couple of 45 deg mirrors can be inserted to deviate the light toward a different doublet, and another couple can deviate again the beam to the detector, creating the 'High Resolution Mode' focus. Each channel will be then split in three subchannels, for reconstruc-

Table 4. BBI Filters list

Filter Name	C [nm]	FWHM [nm]	Spectral Feature
BBI-WF1	388.30	0.5	CN band head
BBI-WF2	395.37	0.5	Ca II H continuum
BBI-NF1	396.88	0.05	Ca II H core
BBI-NF2	396.47	0.05	Ca II H wing
BBI-WF3	417.00	0.5	Paschen continuum
BBI-WF4	430.50	0.5	G band
BBI-WF5	436.39	0.5	G band continuum
BBI-NF3	656.28	0.1	H
BBI-WF6	668.40	0.5	H continuum
BBI-WF7	840.00	0.5	Brackett continuum
BBI-NF4	854.20	0.05	Ca II IR

tion techniques purposes: after the last movable mirror, the beam is split again with two beamsplitters, to form the three subchannels. Filters are placed immediatly before the detectors, so to limitate their dimensions, in a telecentric configuration.

2.3. Performances

Spot diagrams, ensquared energies and throughput at two different wavelengths and for the two observational modes are shown in figures 3 and 4. From their examination it is clear that the optical design satisfies the requirements.

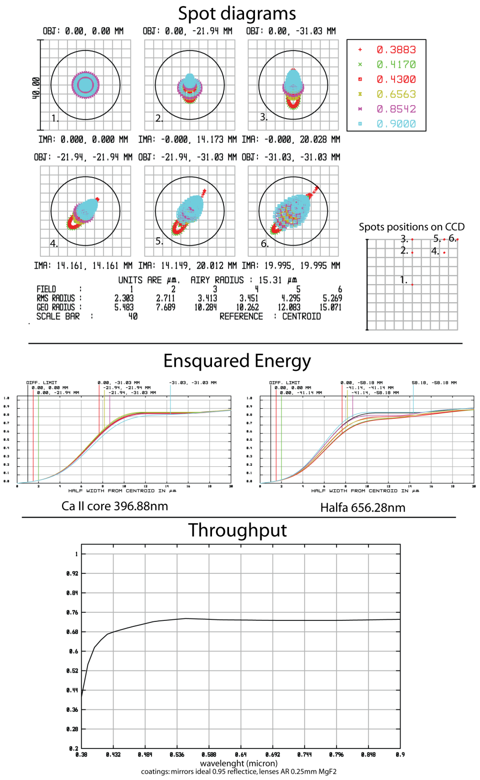

Fig. 3. High resolution mode performances

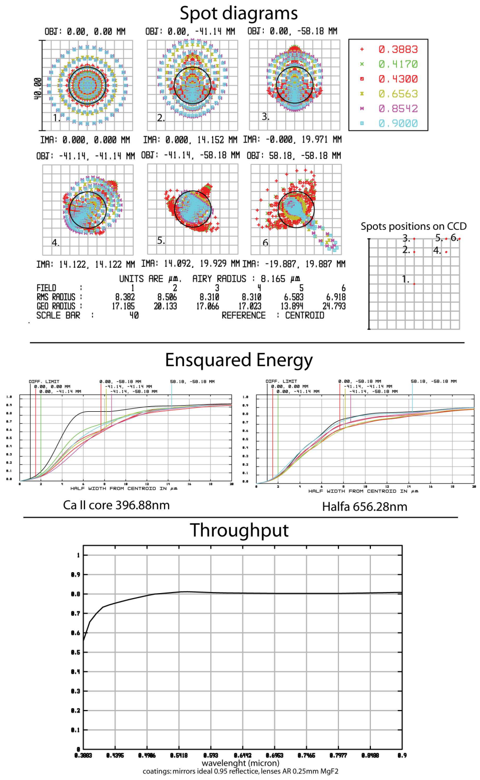

Fig. 4. Low resolution mode performances

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