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The EChO Visible and Near Infrared spectrometer

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Abstract

The EChO Visible and Near Infrared (VNIR) spectrometer will able to cover the spectral range between 0.4 and 2.5 μm. It has to be designed to assure a resolving power of about 320 over whole spectral range. VNIR will be a spectrometer in a cross-dispersed configuration by using a combination of a diffraction grating and a prism to spread the light in different wavelengths and in a useful number of orders of diffraction. It will use a Mercury Cadmium Telluride detector to satisfy the requirements of low thermal noise and the EChO system to operate at the working temperature of 40-45K. The instrument will be interfaced to the telescope optics by optical fibers to assure an easier coupling and an easier colocation of the instrument inside the EChO optical bench.

1. Introduction

EChO (Exoplanets Characterization Observatory) is one of the ESA M3 Cosmic Vision missions selected for the assessment phase. EChO will observe and study the atmospheres of extra-solar planets with unprecedented sensitivity to life-marker gases, in a range of physical conditions down to habitable rocky planets (super-Earths) around dM stars. A substantial fraction of such planets are seen transiting their host stars, and they are the best targets for the EChO mission. EChO is a spaceborne observatory that it would be placed in the L2 lagrangian point and it will be equipped with different module spectrometers to cover the spectral range between 0.55 and 11.00 μm as requirement and a possible extension as goal to the interval 0.4-16.0 μm.
The EChO Visible and Near Infrared module will operate in the 0.4-2.5 μm spectral range with a resolving power better than 300 over all the range and a field of view of approximately 2 arcsec. The module shall have the sensitivity to observe stars with an apparent magnitude M_v=9–12 and reveal exoplanet transits, hence it must be able to see contrasts of the order of 10^{-4}–10^{-5}. The cross-dispersed configuration has been adopted as baseline for VNIR as it has been estimated to be the most suitable and efficient one for our purpose. The instrument will be coupled with the telescope and the optics before it through two optical fibers. The feeding optics of VNIR is composed by the telescope and a series of collimating optics and dichroic elements in order to extract the light in the different spectral ranges relative to the different spectroscopic modules.
The extraction of the spectral range relative to VNIR will be done by a single dichroic element. After the extraction the light will be collimated in a 25 mm beam. Then the beam will be directed toward the VNIR spectrometer and the EChO Fine Guidance System. The spectroscopic modules will be located on the Instrument Optical Bench in the stable thermal environment at 40-45 K.
The performance of the module should be good enough to assure the observations of transient planets in transit or in occultation of a star.

2. VNIR spectroscopic module

The instrument has been designed to actually cover a spectral interval ranging between 0.4 and 2.5 μm without gaps with the requested spectral resolution. The resulting resolving power is nearly constant and it is R≈330.

The spectrum is spread on a 256 by 256 pixels detector. The wide spectral range is achieved through the combined use of a grating with a ruling of 14.3 grooves/mm and a blaze angle of 3.3° for wavelength dispersion in horizontal direction and an order sorting calcium fluoride prism (angle 22°), which separates the grating orders along the vertical direction.

The prism is the only optical element used in transmission. All the other optical elements consist of reflecting surfaces. All the reflecting elements are made from the same aluminum alloy of the optical bench. This solution is used to simplify the mechanical mountings and the alignment of the system so that it can correctly operate at cryogenic temperatures.

The coupling of the VNIR module with the telescope will be done through the use of a dichroic element that will select and redirect the visible and near infrared light, in the wavelength interval 0.40-2.47 µm, towards the combined system constituted by VNIR and the EChO Fine Guiding System (FGS). A second dichroic element placed on the optical path of the new beam, will also partially remove the wavelengths in the range 0.4-1.0 µm to feed the FGS. At present the amount of light available for VNIR in the visible range is about 50% of that originally collected by the telescope.
The light is fed to the spectrometer via two fibers by two identical off-axis parabolic mirrors that collect the light from the telescope in the ranges 0.4-1.0 and 1.0-2.47 µm respectively. Those mirrors are the only optical elements whose positions are bound to the geometry of the EChO common optics. The remaining optical elements of the spectrometer can be freely positioned within the volume assigned to the instrument.

The fibers are made of fused-silica with ultra-low OH content and have a core diameter of 0.05 mm. The entrance beam has a focal ratio F/4.0, the sky-projected fiber diameter is therefore 2.1 arc-sec. The spectrometer is designed to accept a beam aperture of F/3.5 from the fiber. This generous oversizing is included to minimize the light-losses due to focal-ratio degradation within the fibers.

A Mercury Cadmium Telluride (MCT) detector with 30 µm squared pixels has been considered for VNIR. Figure 3 shows the observable spectral orders m projected on the MCT matrix, starting from $m = 3$ at the bottom (near infrared spectral range) to $m = 20$ on the top (ultraviolet spectral range). Namely, the figure shows the distribution of the light on the array between 2500 nm (m = 3) and 400 nm (m = 20). Figure 1 gives the positioning of the spectrum on the VNIR 256 x 256 pixels detector while Figure 2 shows the opto-mechanical layout of the module.

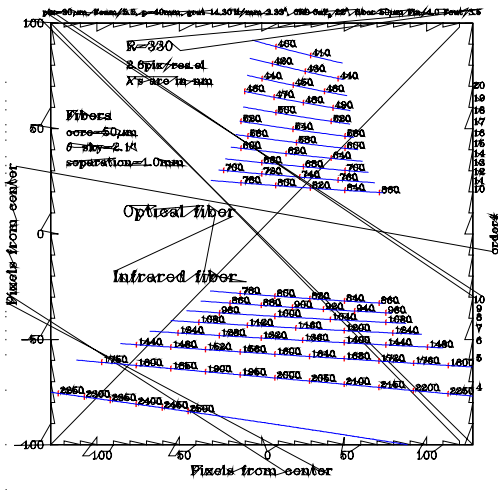

Figure 1: Positioning of the spectrum on the VNIR 256 x 256 pixels detector.

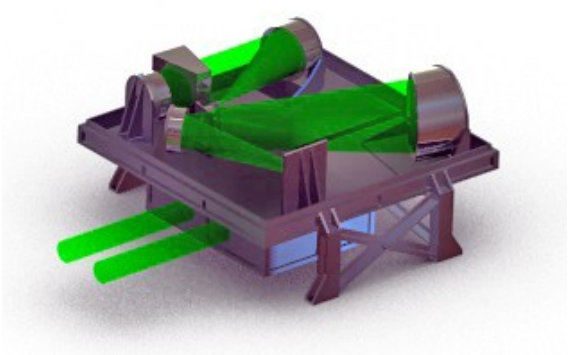

Figure 2. Opto-mechanical layout of the module

Acknowledgements

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