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The integration and alignment phase for the Acquisition and Guiding System of SOXS

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ABSTRACT

SOXS (Son Of X-Shooter) will be the new double-armed spectrograph for the ESO NTT at La Silla and it will be optimized to provide an unique specialized facility to follow up and classify any kind of transient events. It consists of a central structure (common path) which supports two spectrographs optimized for the UV-Visible and a Near-IR range. Attached to the common path there is the Acquisition and Guiding Camera System (ACS), equipped with a filter wheel which can provide some science grade imaging and moderate high speed photometry. The project is currently in its Assembly Integration and Verification phase following a modular approach so that each sub-system can be integrated in parallel before their final assembly at system level, foreseen at the INAF-Osservatorio Astronomico di Padova (Italy). The optics and the mechanical parts of the ACS arrived in the second semester of 2021, so from that moment the Assembly and Verification Phase began. This work presents the assembly and testing operation of the ACS of SOXS and we report the strategy and the results achieved to meet the requirements.

Keywords: Spectrograph, Transient, Medium-Resolution, NTT, AIT

1. INTRODUCTION

The Son Of X-Shooter (SOXS), is a spectroscopic facility for the European Southern Observatory (ESO) New Technology Telescope (NTT) at La Silla Observatory, Chile.[1,2] It will be dedicated to the follow-up of transient sources, proposed by an Italian led consortium. It will be a two arm spectrograph able to cover the optical/NIR band ($0.35-1.8\mu m$). SOXS will be a medium resolution spectrometer ($R\sim 4500$) with light imaging capabilities in the optical with multi-band photometry for faint transients. The spectrograph is divided into five sub-systems: Common Path (CP),[3,4] UV-VIS spectrograph,[5] NIR Spectrograph,[6] Calibration Unit,[7,8] and the Acquisition Camera (AC).[9]

The backbone of the system is the CP, which receives the light from the telescope and distributes light to the sub-systems, see Fig. 1. The AC will receive the light from the CP through a 45° mirror, called Selector Mirror, which has three permitted working positions: monitoring (takes the light that surrounds a $15asec$ hole), simulate an artificial star for calibration purposes (take the field surrounding a $0.5asec$ hole), and the imaging mode (full field).[8] These functions will allow the AC to do photometry, to work in the acquisition of the target for spectrographs, for monitoring of spectrographs co-alignment, and also can be used as a guiding system if needed.

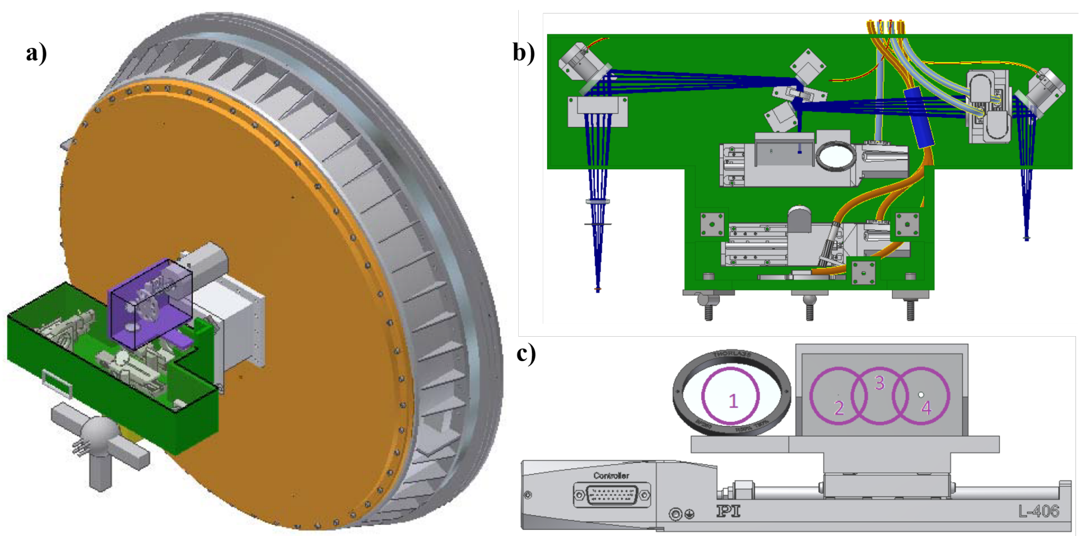

Figure 1. Acquisition Camera and Common Path. a) CP (green) is mounted in the Nasmyth interface of the NTT in La Silla and the AC is on top (purple). b) General CP view, the light beam entrance is in the bottom center and the CAM selector send the light to the AC Unit. c) CAM selector with circles indicating the working position.

SOXS was supposed to start operations in late 2020, replacing the current NTT instrumentation, but unfortunately the project has suffered a considerable delay due to the pandemic and problems with suppliers. Currently, the instrument is being integrated and is close to being completed. This work will discuss the AC properties and its components, the optomechanical tolerances, the integration and testing procedures, and problems and adjustments that were made during the integration.

2. ADQUISITION CAMERA OVERVIEW

The AC Unit consists of a Collimator Lens (CO), a folding mirror (FM), a filter wheel (FW), and a four lens camera, see Fig. 2. The focusing mechanism is the CO, which is mounted in a linear stage. The filter wheel also uses a rotating mechanism in order to choose between a broad-band filter set (ugrizY and V-Johnson). The detector is a 1024x1024 Andor iKon-M 934 camera, and the control software was developed and validated by SOXS Consortium.[10,11] The system includes a CAM selector, which will be mounted in the CP. The CAM Selector carries a pellicle beam-splitter and the selector mirror (SM). All the system is included in a structure made of 6061-T6 Aluminum and is anodized.

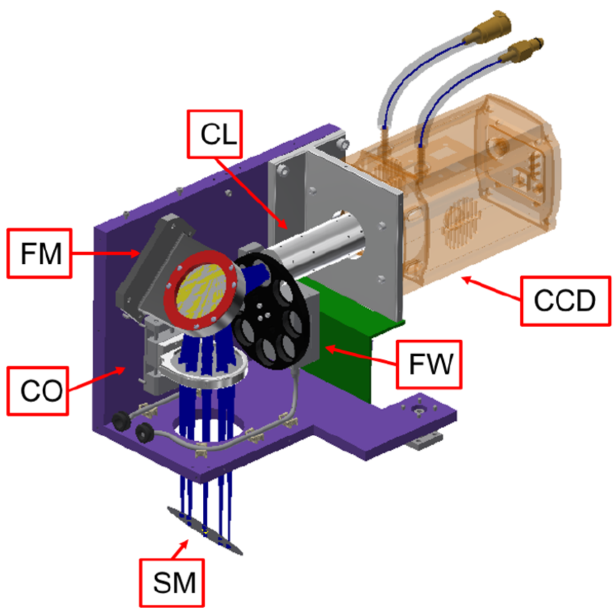

Figure 2. AC Unit and its components.

The AC Unit acts as a focal reducer, it reduces the incoming F/11 beam to a F/3.6. Each pixel of the CCD camera 13.0μm will correspond to approximately 0.2$asec$, resulting in a 3.5$amin$ unvignetted field of view. The image quality is such that over 90% of the geometrically encircled energy is contained in two pixels for a central field of 6.5mm radius.

At the beginning, the design considered a detector wavelength range that extends up to 1 micron with an QE above 20. However, the requirements was not met for the u and y filters, the main reason is the sensitivity of the detector which focuses more over a wavelength range that goes from 400 to 900nm.[12] The AC unit still considers the u and y filters but they have a lower transmittance, see Fig. 3. These curves include the optics, the filters and the atmospheric effect.

A Monte Carlo Analysis made shows that the performance will keep light in two pixels in 80% of the runs and from then it can get up to three pixels, 55000 Monte Carlo files were generated. The worst offenders are contained in the four lens camera, so this was one of the most challenging pieces to align. In general, the optics manufacturing tolerances used are the Optimax precision quality.[13]

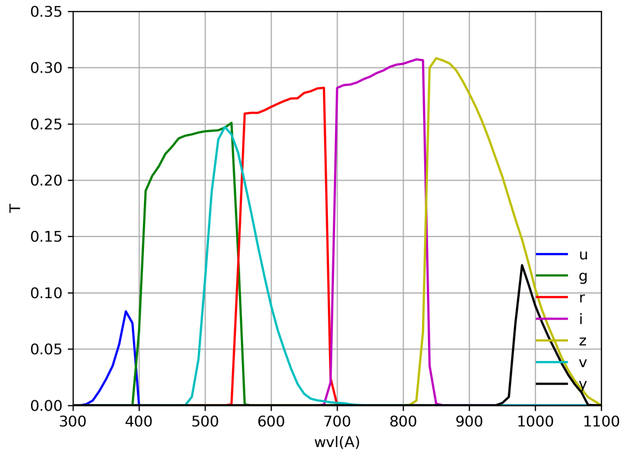

Figure 3. Final filters Transmittance. The curves include the broadband filter set: ugrizY and V-Johnson, plus the atmospheric effect.

3. AC COMPONENTS

The components began to arrive from the year 2019. The Andor camera, the linear and rotatory stages and the filters arrived first. Later we had problems with the suppliers due to the pandemic lockdowns and as soon as activities resumed we had the mechanics and finally at the end of 2021 the optical components arrived at Padova. The AC Unit was assembled at the INAF-Osservatorio Astronomico di Padova and then mounted to CP that was already fixed in the flange of the telescope simulator. In this section the components that conform the camera will be described, in order to talk about the manufacture of the components, the procurements, and the situation that complicated the integration process and the adjustments that were made.

3.1 Selector Mirror

The selector mirror procurement was complicated because in the first design the pinholes were supposed to be drilled to a rectangular flat mirror of 70 x 97 x 10 mm. After considering a few experimental procedures the AC team and the Consortium decided to instead of drilling in the mirror substrate to introduce a metallic plate with the hole. This mirror is going to be tilted at 45° so the shape of the holes are elliptical, see Fig. 4. We refer to[8] and[14] for a more detailed description of the CAM selector system and its functionalities.

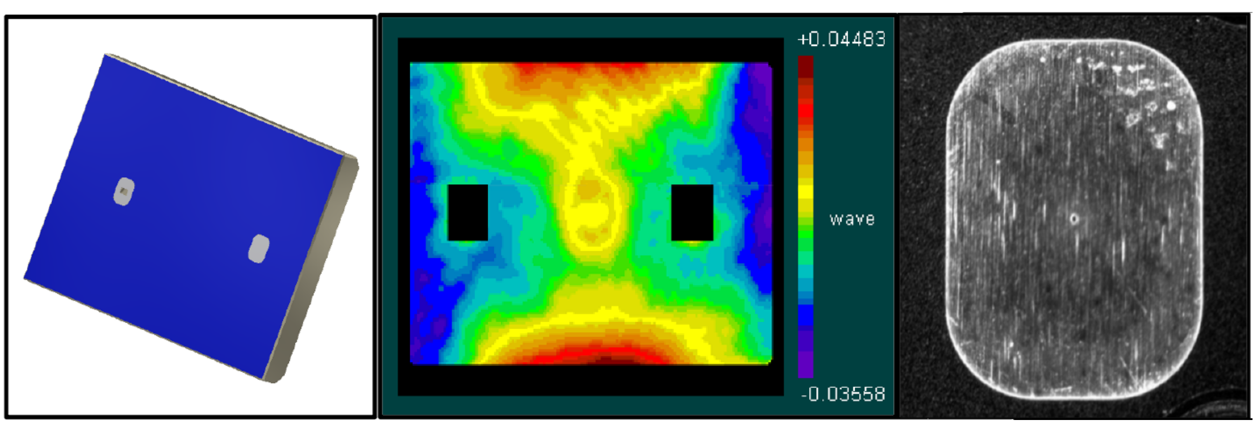

Figure 4. Selector mirror. Left Panel: View of the SM. Central panel: Wavefront Map of the SM (PV: 0.161 fr; RMS: 0.014 fr). Right panel: Zoomed view of the metallic plate for the Artificial Star Mode.

3.2 Collimator and Linear Stage

The collimator lens also had a change from the first design. Initially the lens was made of Calcium fluoride $CaF2$ but the fabricator said that there was a problem with the delivery time of this material, after a slightly change on the design the material changed to a $N-FK58$ from Schott. The lens arrived at the end of 2021 and met the requirements. Another important aspect of this element is that this will be the focusing element, the lens is mounted in a PI stage $M-111-1DG1$, this is a high resolution micro translation stage with 15 mm travel range, shown in Fig. 5.

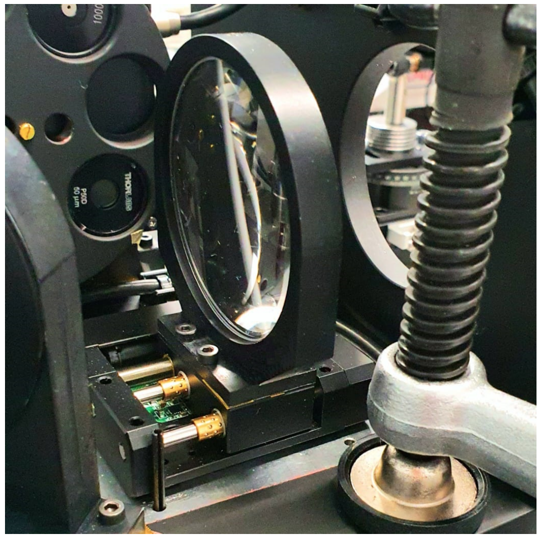

Figure 5. Collimator Lens.

3.3 Folding Mirror

The folding mirror is a 60 mm diameter mirror with a flat surface and fulfills the requirements. The mirror takes the collimated light and directs it towards the camera. The mount is very simple, as shown in Fig. 6.

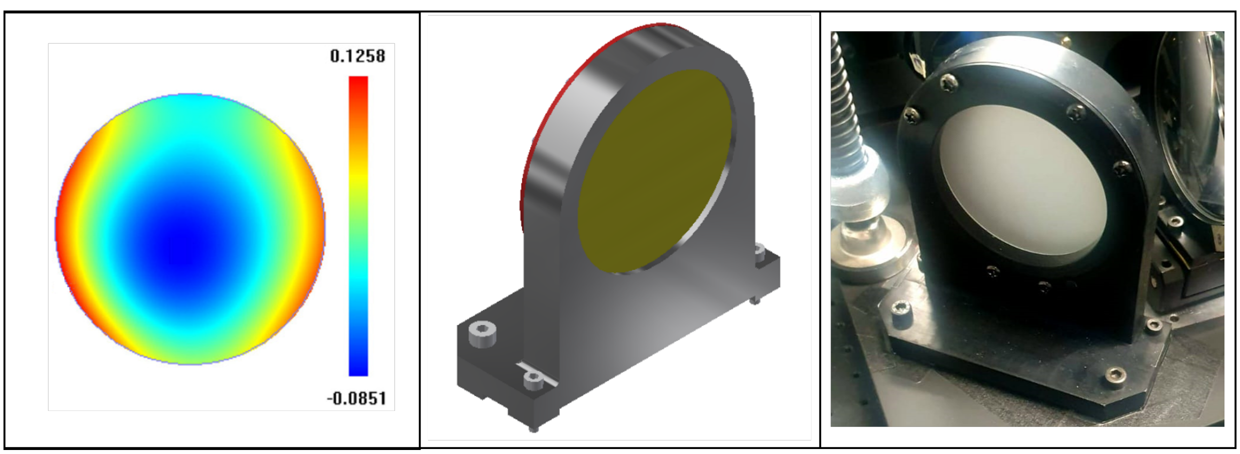

Figure 6. Folding mirror. Left Panel: Wavefront Map of the FM (PV: 0.2109 fr ; RMS: 0.0491 fr). Central panel: view of folding mirror. Right panel: picture of mirror seen from behind.

3.4 Filter Wheel and Filters

The filter wheel is a custom made item, made by Thorlabs. The wheel has a 105 mm diameter with 8 circular apertures with a 22.2 mm diameter that has SM1 threads. The filter wheel is mounted in a PI stage $M-116.DG$, this is a micro rotation stage with preloaded anti-backlash worm gear drive. It has 360 degree continuous rotation and a $50\mu rad$ minimum step. The filters are from Asahi Spectra, see Fig. 7.

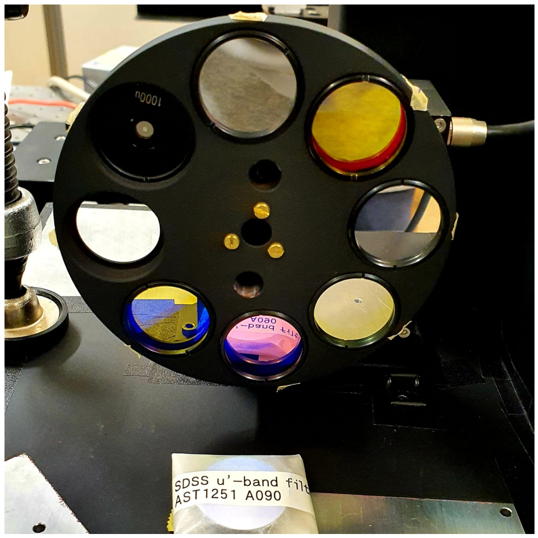

Figure 7. Filter Wheel and filters.

3.5 Camera Lenses

The camera tube is the most important element in the assembly. It is formed by two cemented doublets and two singlets and is this tubular structure that is anchored to the CCD mounting. The tolerance analysis showed that the first doublet from the lenses was one of the worst offenders and also the separators needed to have a precision of 0.05 mm. The lenses met the quality criteria but unfortunately one of the separators didn't, there was a 0.07 mm decenter and it was replaced by a new one.

Figure 8. Camera Lens: optics and mechanics.

3.6 Andor Camera

The detector system is an Andor iKon $M - 934$ with a CCD sensor $BEX2 - DD$. This CCD is known for its high-sensitivity and low noise performance, with up to $5MHz$ pixel readout. The control software was developed and validated by SOXS Consortium,[11] see Fig. 9.

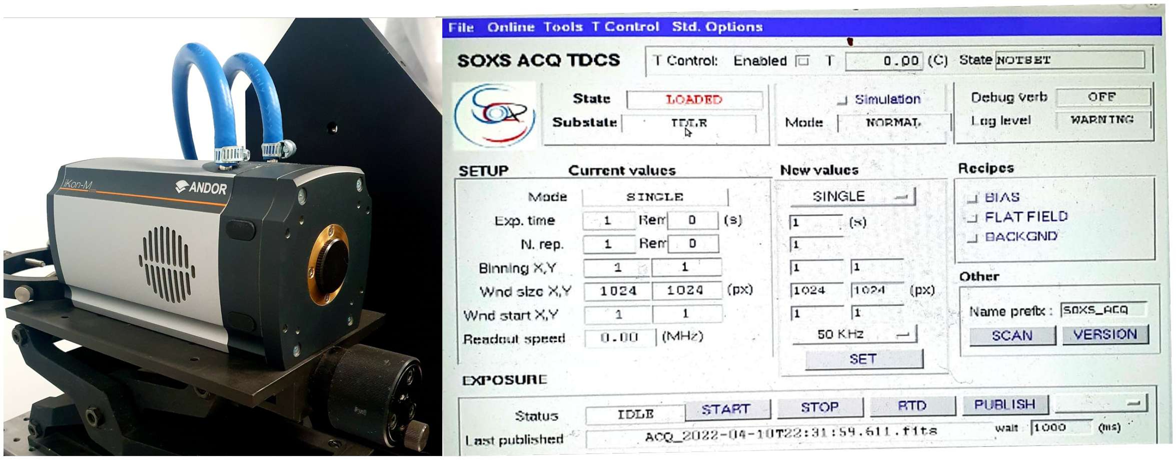

Figure 9. Andor Camera.

3.7 Case and mechanical structures

The system is enclosed in a box of 270 x 225 x 200 mm. The total mass including all the kinematic mounts, the camera, the optics and stages is 11kg. It has a main T-shape structure made of aluminum $6061 - T6$. To ensure maximum stiffness all the walls are structural with thickness of around 15 mm. The cover is made of a 3 mm thick aluminum plate. The centering of the CCD was made by shimming the 3 holes and 3 dowel pins used to place the CCD. The following picture shows the AC Unit mounted in the CP, see Fig. 10.

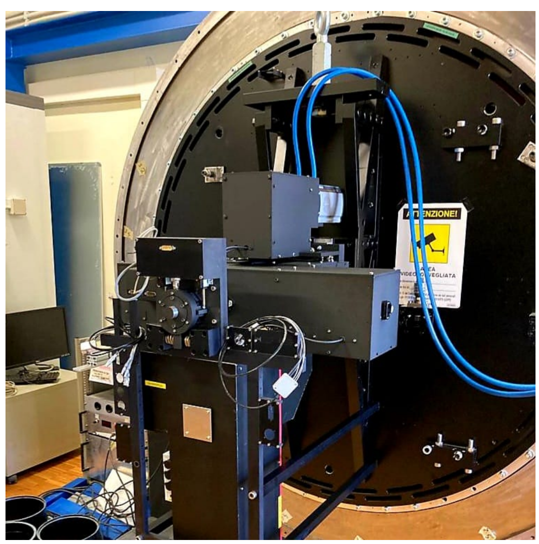

Figure 10. AC Unit and CP in Telescope Simulator.

4. CONCLUSIONS

After a long time of waiting, we managed to have all the components to start the assembly, integration and testing. The components arrived by the end of 2021 and the assembly started at the beginning of 2022. The work was carried out at the INAF-Padova facilities. At the moment the alignment is still on-going, unfortunately there was a problem with one of the separator rings that hold one of the doublets and right now it's being aligned in order to attach the camera lens to the CCD. By now, we have been working with the Andor camera without any issue. The stages work fine and achieve the repetitively that is required. And the mechanics were done properly and the kinematic mounts fit properly when the AC unit was mounted in the common path. At the moment we are waiting to start the distortion and resolution tests.

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