Testing activities with existing equipment at Helmos Optical Ground Station.

Final Report

The set of equipment delivered by ESA has now been assembled at Helmos and the different components attached to the telescope. Preliminary tests have also been performed.

The Transmitter (Tx) system

For the transmitter (Tx) system a subset of the equipment have been attached to one side of the 2.3 m Aristarchos telescope and another placed on the azimuth platform of the telescope. The set of equipment attached to the side of the telescope consist of a Galileo type transmit telescope (with an 80 mm diameter front lens) and a fiber amplifier (IPG, model YAR-100-1064-LP-SF) mounted to the right of the transmit telescope and connected via a large core diameter single-mode fiber (see Fig. 1a).

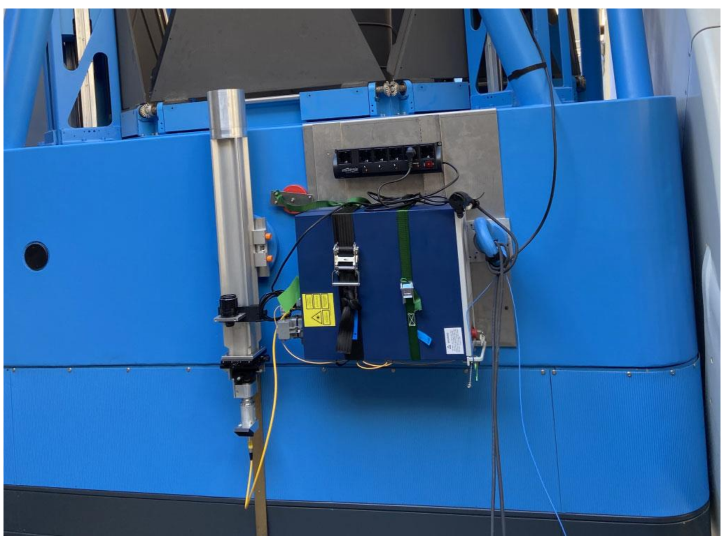


Fig. 1a: *Transmitter telescope and optical fiber amplifier attached to the side of the main 2.3 m telescope.*

Fig 1b: *Transmitter modulation system rack containing Coherent seed laser, Photline modulation system, Yokogawa wavemeter and Rigol oscilloscope.*

The transmit signal is generated by a non-planar ring oscillator seed laser (Coherent, model Mephisto 500NEFC), intensity and phase modulated (Photline, model MODBOXEDRS-1064 nm) and single-mode fiber coupled to the IPG amplifier. The transmit frequency is monitored via wavemeter (Yokogawa, model AQ6151B) and the pilot tone is both generated and monitored by a multi-function oscilloscope (RIGOL, model DS1074). The modulation system rack is shown in Fig. 1b.

The Receiver (Rx) system

Fig. 2 shows the 2.3 m Aristrachos receive telescope's receiver system. In detail, it consists of a mechanical shutter and a 70 nm wide band-pass interference filter (Semrock, model: FF01-1055/70-25), which reduces the blue-sky brightness sufficiently for daytime operation and transmits enough optical spectrum to detect stars for telescope pointing calibration, a tip/tilt mirror (Optics in Motion, model: OIM102.3), a motorized quarter wave plate (QWP) to change into linear polarization and a polarizing beam splitter (PBS). Rotation of the QWP enables adjustment of the PBS splitting ratio between camera and interferometer. The PBS splits the beam towards an InGaAs camera (First Light, model: C-RED 2) and a bit-delay interferometer that converts binary phase shift keying (BPSK) modulation into intensity modulation.

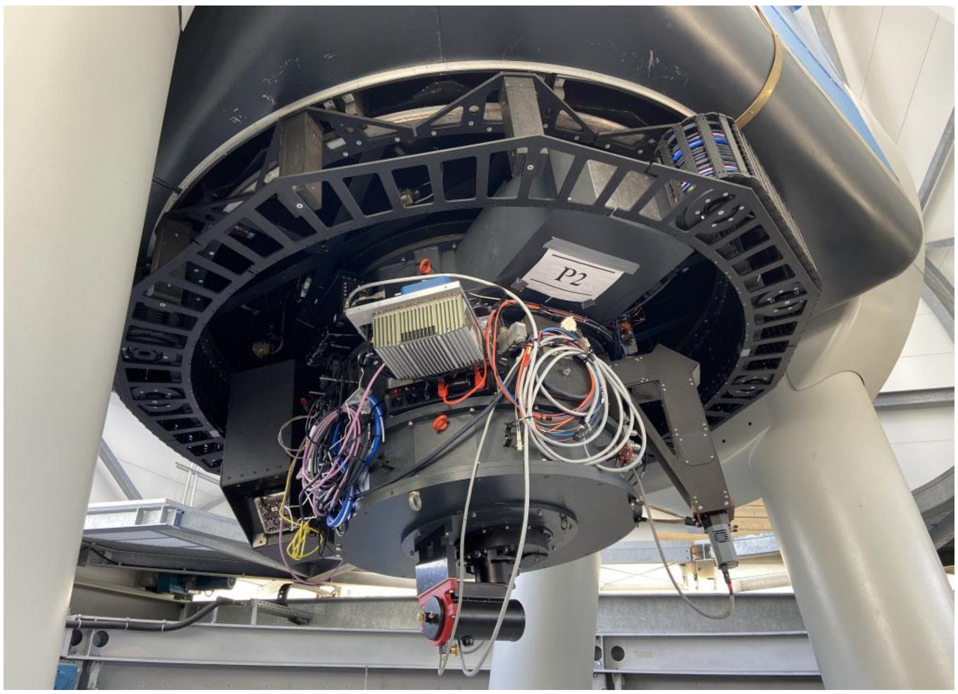


Fig. 2: *Receiver system attached to a side port of the Cassegrain focal plane. A small industrial tracking computer with silver-colored fins in the center of the image is mounted to an aluminum plate on top of which the receiver instrumentation is located.*

The optical path difference (OPD) in the interferometer is introduced by a glass block (GB) and set to match the time duration of one bit (2.8125 Mbps). In addition, fine adjustment of the OPD by a piezo stage is required to compensate for thermal expansion of the interferometer and for Doppler shifts of the received signal.

The Transmitter/Receiver Alignment system

Fig. 3 shows an electrically rotatable retro-reflector bar (PLX, model L-20-1-500MM) attached to the ring holding the secondary mirror (at the top of the telescope), which is used to align the pointing direction of the transmit beam (diameter: 40 mm) with the optical axis of the 2.3 m receive telescope. The retro-reflector bar (RRB) laterally offsets the transmit beam by 500 mm such that it reaches the primary mirror. During alignment the fiber amplifier is switched off, the seed laser which is propagating through the amplifier is sufficiently strong to be detected by an InGaAs camera in the focal plane of the 2.3 m telescope.

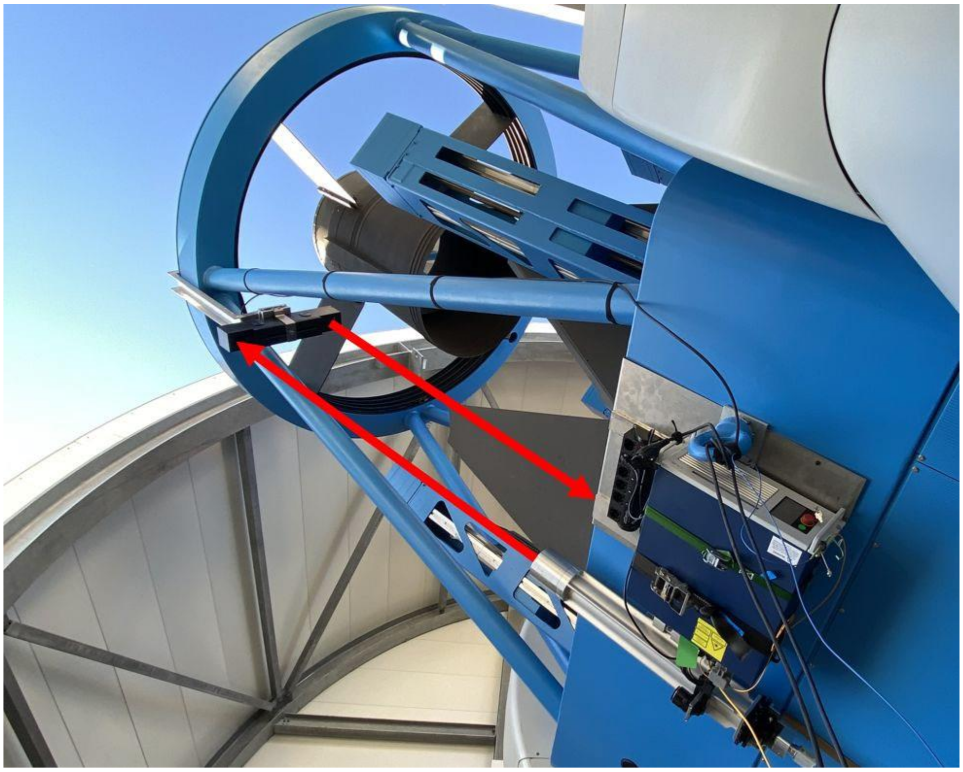
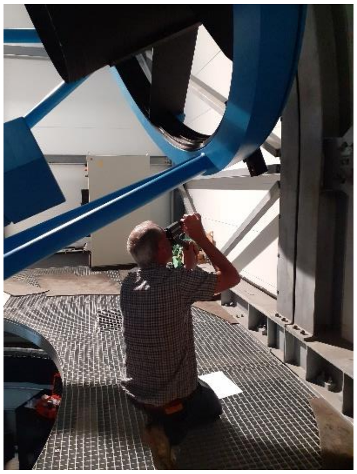


Fig. 3: *Alignment of the transmit beam pointing direction with the optical axis of the telescope. The laser beam leaving the transmit telescope and offset-reflected into the 2.3 m telescope via a retro-reflector bar is indicated with red arrows. After alignment the retro-reflector bar is rotated out of the transmit beam.*

Testing the Tx/Rx system

Once the system was installed at the Aristarchos telescope the NOA team assisted ESA to perform preliminary tests. In particular, the telescope was balanced (using extra weights that were placed at the Cassegrain focus part of the telescope in order to counter-balance the weight of the systems attached to the telescope.



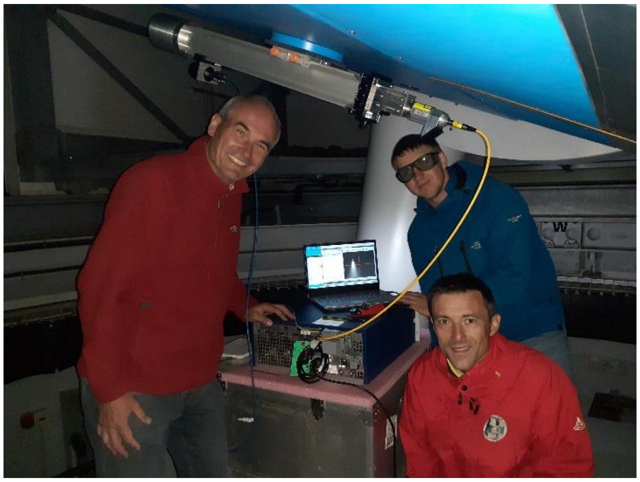


Fig. 4: *The first tests performed to align the Tx/Rx system.*

As a next test the alignment the alignment of the Tx/Rx system took place. Aristarchos telescope was carefully focused on a star, because the out-off-center transmit beam alignment via the retro-reflector bar would introduce a lateral shift of its point spread function (PSF) in case of defocus. Its light being centered, a lateral shift does not occur to the PSF of a star (or the satellite). Due to diffraction the PSF of the alignment beam is about 60 times larger in diameter compared to the PSF of the star. The retro-reflector bar was suspended from the ring holding the secondary mirror to allow for its motorized rotation (out of the transmit beam) between two beams of the "Serrurier" truss (see Fig. 4). In parallel to these activities a Satellite Tracking Software was implemented to the existing control system of the telescope. This new software allows the telescope to be used to track satellites in MEO, GEO, at the Moon and in deep space, but will fail at velocities required for LEO satellite tracking, for which a replacement of the original Aristarchos telescope control system (ATCS) is required. Throughout the software implementation a large number of tests were performed on the various functionalities of the telescope with the NOA staff assisting the ESA team in all procedures.