LEOCAT: Low SWaP, low recurring cost optical head for intersatellite optical communication

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TNO innovation for life

LEOCAT is an optical head for intersatellite communication currently under development by TNO (ESA ARTES contract). The objective of LEOCAT is to develop a low recurring cost low SWAP (Size Weight and Power) optical head for the optical satellite communication constellation market. The aim of LEOCAT is to achieve a data-rate of 10Gbit/s over a distance of 4400km.

The optical head is the opto-mechanical heart of the terminal, containing the telescope, fine steering mirror (FSM) for tracking of the incoming Rx beam, Point Ahead Mechanism (PAM) to correct for the point-ahead angle of the outgoing transmitted (Tx) beam and all the optics up to the detectors and Rx/Tx fibres. Other parts of the terminal such as the coarse pointing assembly, electronics and laser are out-of-scope of the LEOCAT project.

KEY SPECIFICATIONS AND CHALLENGES

Early concept designs and link budget assessments identified that the means to achieve the lowest recurring cost are to design a compact system. To achieve the bit rate with a compact system requires a low WFE and µrad level pointing accuracy of the transmitted (Tx) beam. Additionally, for the production of larger series it is desirable to split the design into modular blocks that can be produced/assembled in parallel, with an almost "plug-and-play" (minimal alignment) final assembly. From constellation architectures it is assumed that there will be 4 terminals per satellite, 2 male (1556nm) and 2 female (1535nm). Based on the link budget assessments and use case analysis, LEOCAT has been designed to the top level requirements shown in the table below.

Requirement	Value
Entrance pupil diameter	70 mm
Wave-front error of full Tx channel	<85 nm RMS
Mass Optical head (excl detectors and FSMs)	<3 kg
Pointing error Tx	<3 µrad
Survive a quasi-static load up to	100g
Operational temperature range	-20°C - +40°C
Non-operational temperature range	-40°C - +60°C

OPTOMECHANICAL DESIGN

The design is based on an all metal a-thermal design, supported on Ti6Al4V struts for strength and thermal isolation. The design consists of high TRL building blocks such as flight proven optical mounts and micron level stability fibers. An overview of the design of LEOCAT is shown in Fig. 1.

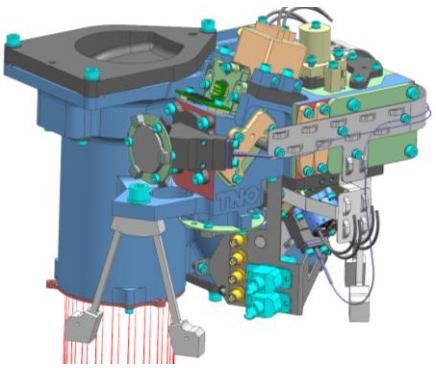

Fig. 1. Overview of the opto-mechanical design of the LEOCAT optical head

The telescope is an off-axis telescope with a 70 mm pupil located at the entrance of the optical head. It has 4 reflections with a magnification of 1/8 and field-of-view (FOV) of 0.25 degrees. The design of the mirrors has been done in order to allow multiple mirrors manufacturing on the same lathe at the same time, therefore enabling low recurring price and fast delivery times.

In order to achieve a good fibre coupling of the incoming Rx data signal as well as a low Tx pointing error an FSM is placed at the exit of the telescope in the common path of the Tx and Rx signals. The TNO high speed FSM is operated in closed loop (tracking bandwidth of about 1.7 kHz) with the incoming Rx signal on a tracking quad cell. Micro-vibration analysis assuming a typical spectrum shows a reduction from a base-excitation of 16 µrad RMS to 0.3 µrad RMS should be possible with the current design.

The Tx and Rx channel alignment could drift due to for example sensor drift and thermal effects. A calibration function is implemented in the design that allows calibration of the Tx channel to the Rx channel. The pointing error between the Tx and Rx channels can be measured after which a new set-point/offset for the PAM mechanism in the Tx channel can be given. It is under investigation whether the PAM can even be operated in closed loop, enabling continues calibration of the Tx to Rx channel thus allowing continues links.

STATUS

The LEOCAT EM is currently in the assembly phase with functional testing to be completed at the end of 2019. The WFE of the telescope is measured to be well within the specification with a value of 34nm RMS. For series production some design aspects can be relaxed resulting in a cheaper product.

The design and hardware are prepared for the space environment and environmental testing could potentially be performed on the EM with minimal changes. Industrialization of the LEOCAT system is being investigated together with the Dutch consortium FSO instruments BV.

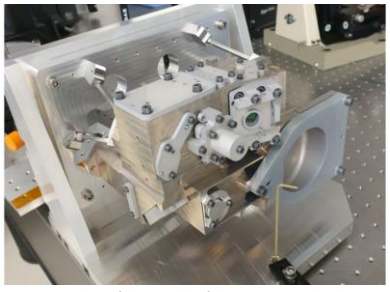

Fig. 2. Photo of the assembly of the LEOCAT optical head

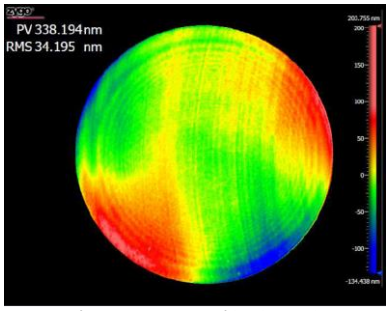

Fig. 3. Interferometer measurement of the telescope, showing a WFE of 34nm RMS.

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