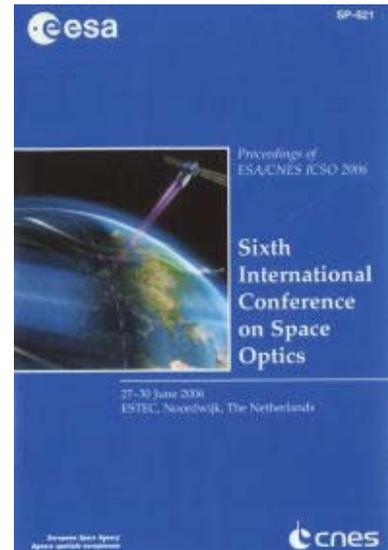


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SELECTED TECHNOLOGIES FOR INTEGRATION OF THE ALADIN TRANSMIT-RECEIVE OPTICS (TRO)

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ABSTRACT

Selected technologies for the integration of the TRANSMIT/RECEIVE OPTICS (TRO) are presented. One of the challenging characteristics of the TRO is its stringent requirement on opto-mechanical stability. The stability performance of the TRO must be ensured for the relevant interface environments (thermal, structural) over the 3 years mission lifetime. Comprehensive analyses have been conducted, which have confirmed the need for the development of special integration technologies. Also, dedicated test equipment has been developed to precisely verify the TRO's opto-mechanical stability. Another important feature of the TRO is its exposure to the high power laser beam of the ADALIN instrument. The corresponding optical elements and their mounts must survive exposure to light intensities up to the required laser-induced damage thresholds (LIDT). Two types of adhesives for gluing of the TRO optics have been selected. Their qualification w.r.t. outgassing was necessary since LIDT's of optical surfaces are significantly reduced when organic outgassing products are deposited there.

1. INTRODUCTION AND DESCRIPTION OF THE TRO

The ADM-AEOLUS mission by the European Space Agency (ESA) has been published by ESA⁽¹⁾. The satellite is developed for ESA with EADS Astrium as prime contractor for the satellite and the instrument. In the following an introduction to the ALADIN TRO is given.

The overall opto-mechanical layout of the TRO is shown in Fig 1. All optical and mechanical parts are integrated on one main structure, the so-called TRO base plate. The TRO will be interfaced to the ALADIN optical bench by three bipods.

The ALADIN laser beam (beams are coded in yellow colour) enters the TRO from the left. The spectrometer output is in the upper right. A beam splitter separates the incoming beam into the emission path (back reflected) and the calibration path, the latter is superimposed onto the reception path (lower centre on Fig. 1).

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The emission path is expanded by a factor of 1.33 and enters the so-called Diplexer Cube. This opto-mechanical assembly houses a polarising beam splitter, a QWP, and a HWP to implement the optical function necessary to emit the laser light and to receive the atmospheric return via the same telescope. Furthermore a light trap is attached to the cube for suppression of remaining parasitic reflections at the cube as well as of stray light of the laser beam. An interference filter in the reception part of the cube eliminates earth background radiation in the wave length band from 300 to 400 nm.



Fig. 1: Opto-mechanical layout of the TRO (stray light covers removed)

The reception path is made up of two afocal optical relay units (Relay I and Relay II, each designed as two lens triplets) with intermediate foci. The first focus is used by a Laser Chopper Mechanism (LCM) to block the reception path during laser fire, while the pinhole located at the focus of Relay II determines the very narrow FOV. The LCM is not part of the TRO. A spectrometer like optical set-up using a prism together with the two very small pinholes sufficiently suppresses off-

axis light and blocks off background radiation at broad band scale. Prism and interference filter together provide the required background suppression ratio for the Aladin instrument.

A reflective beam expander enlarging the nominal beam diameter from 10 to 36 mm forwards the beam to the Aladin telescope (beam perpendicular to the TRO base plate in Fig. 1).

The calibration path is expanded by an aberration generator, bypasses the telescope port, transmits through grey filters for beam attenuation, and a blocking prism, and is then overlaid to the reception path.

The optical design of the TRO has been published earlier⁽²⁾⁽³⁾.

2. MECHANICAL STABILITY OF THE TRO COMPONENTS

One of the most stringent requirements for the TRO is the opto-mechanical stability. The long-term stability of the TRO (3 years mission lifetime), i. e. output beam stability with respect to the unit interface in rotation must be better than 50 μ rad. Three engineering disciplines are involved in the opto-mechanical design of the TRO: Optical, Thermal, and Mechanical including structural aspects. As an example the operational temperature for the TRO ranges from 15 to 30 degrees Celsius. For stability iterations the starting points were thermal and structural models derived from a best guess mechanical design chosen to mount the optics. The required thermal and structural load cases were applied to the structural model to solve for the rotation and displacement of the optical element.

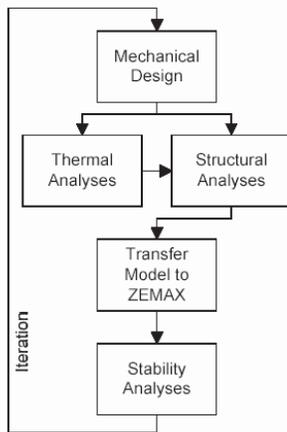


Fig 2: Stability analyses process

A special “bridging tool” was developed, which transferred the results of the structural analyses to the opti-

cal design and analysis tool ZEMAX for beam stability analyses. With this procedure feedback to the opto-mechanical design is possible resulting to the next design iteration. Fig. 2 illustrates the stability analysis process. It must be pointed out, that this is not an automated procedure, and high level of engineering judgement is required.

An example of the design iteration process is given below: The ZEMAX analyses showed insufficient optical stability of a flat fold mirror due to CTE mismatch between the optical element (made of Suprasil) and its mount (Titanium). The mirror was mounted with structured glue. The three arms holding the mirror must have the same stiffness to achieve the lowest mirror distortion, thus, requiring an identical mechanical design for all three arms. This is shown in Fig. 3. The slit at the lower arm has finally been implemented to account for identical design. For illustration the glued hardware is shown in Fig. 4.

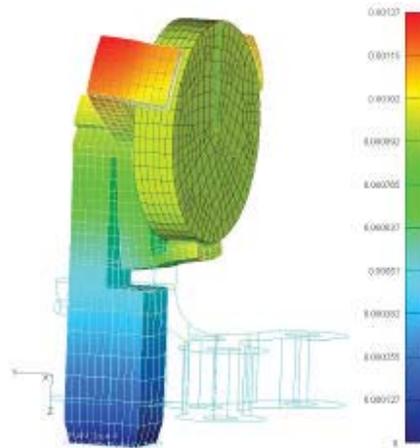


Fig 3: Structural analysis of a fold mirror



Fig 4: Glued fold mirror

3. ATHERMAL DESIGN OF LENS TRIPLETS

Due to the stringent stability requirements for the wave front an athermal behaviour particularly for the lens triplets Relay I and II is necessary. This is due to the intermediate foci inside Relay I and II. Fig. 5 shows the realised concept: A Titanium housing holding the three mounted lenses is surrounded by a shim made of space proven plastic material, which compensates for thermal focus shift due to Ti/Suprasil mismatch. The selected material features very low outgassing properties as well as a very small thermal hysteresis. The CTE and the Young modulus for the raw material batch were measured, since these values typically vary from batch to batch for plastic materials. The length of the shim was designed to match the exact CTE of the used batch.



Fig. 5: Lens triplet housing with plastic shim

4. SELECTED GLUING TECHNOLOGIES

The main requirement for the qualification of glues is extremely low outgassing (CVCM ≤ 0.01 , TML ≤ 0.1), because the TRO is part of the high power path of the ALADIN instrument. Two different opto-mechanical approaches for the various elements made it necessary to use a rigid, structural glue as well as a soft adhesive, the latter in order to damp mechanical loads. Outgassing tests on different glues were performed. Two types of glues (one soft and one structural) have been selected. The identification of the glues was accompanied by corresponding development of opto-mechanical solutions supported by a comprehensive test programme (e. g. structural tests, thermal tests, shear tests).

As an example Fig. 6 shows the same lens triplet as in Fig. 5, however, under a different orientation. Two glued lenses are close to the top of the housing, the third has been integrated at the opposite end. The diameters of the lenses are around 11 mm. Each lens has been glued to the housing by means of four gluing

points with a typical length of 4-6 mm. The selection of glue as well as the number and size of the gluing points were the result of stability analyses. The glue can be identified in the figure by its grey colour.



Fig. 6: Successful gluing of three lenses

Fig. 7 shows the gluing of one of the two prisms into the mount. The four gluing points (one on each side) here have only a diameter of about 2 mm. The violet colour in the picture comes from the applied coating on the prism.

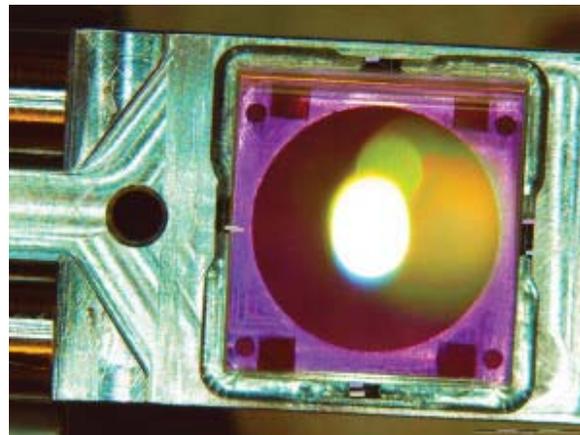


Fig. 7: Successful gluing of a prism

5. LIDT CONSIDERATIONS

A feature of the TRO is its exposure to the high power laser energy on the emission path, which requires special qualification with respect to laser induced damage thresholds (LIDT). There are two groups of affected materials: (1) glass and optical coatings on the emission path, (2) surfaces on the light trap and the LCM blade.

Two types of glass are used: Suprasil and crystalline Quartz for the QWP and HWP. The TRO high power path contains six different optical coatings. LIDT qualification measurements were successfully conducted for all used glass/coating combinations on the emission path. During the production of the FM high power coatings LAT samples were coated in parallel and currently being tested with respect to LIDT. The technology of ion-plating has been selected for the optical coatings, additionally featuring excellent adhesion and abrasion performance, gamma-ray radiation resistance, and no air/vacuum transition.

Unavoidable parasitic reflections of the laser beam at the Diplexer Cube and the QWP have to be taken into account as mentioned before. These parasitic beams are focussed into the light trap (behind the Diplexer Cube) and onto the blade of the LCM (caused by the reflection on the QWP). Fig. 8 illustrates the ray tracing model based on an intermediate light trap concept for the TRO at the Diplexer Cube (the item in the middle with the optical element tilted by 45 degrees). The draft light trap is on the right, the entrance to the LCM below the cube. Despite very low in reflection the laser energies at the foci are high enough that qualification of the involved materials with respect to LIDT needs to be considered.

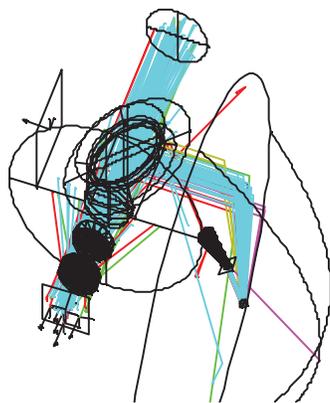


Fig. 8: Ray Tracing around the Diplexer Cube (intermediate light trap concept)

Different materials in the inner part of the light trap have been tested with respect to LIDT performance

with a wide range of laser damage thresholds. Some of these materials have turned out to be safe with respect to LIDT, others are more critical. The final selection of materials is in progress and as a consequence, the final layout of the light trap.

6. MEASUREMENT OF OPTO-MECHANICAL STABILITY

The TRO provides six optical ports (redundant laser In/Out, telescope In/Out, laser In, spectrometers Out). These ports have to have pointing accuracy and stability requirements with respect to each other and with respect to mechanical references in the 50 μ rad range. In order to adjust these ports and measure their stability mainly two setups are employed.

The first one is a set-up to align and measure the bore sight difference of about 125 μ rad between emission and reception path which is shown in Fig. 9. A laser is fed into the spectrometer port. The laser input port is terminated by a cube corner. The CCD is able to measure the angular distance of two beams at the telescope In/Out port. A CCD image of pre-test is shown in Fig. 10. The centroids of the two Areas of Interest give the simulation of the radiation as shown in Fig. 10.

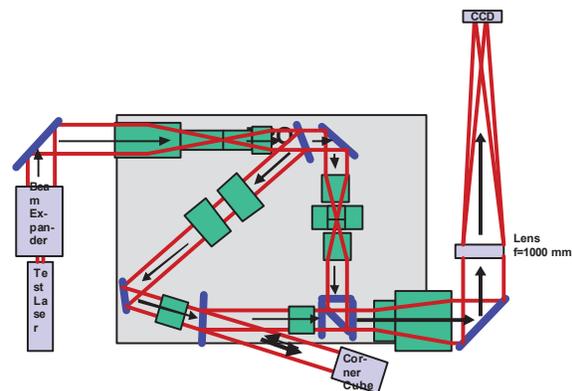


Fig. 9: Emission to Reception Path Boresight

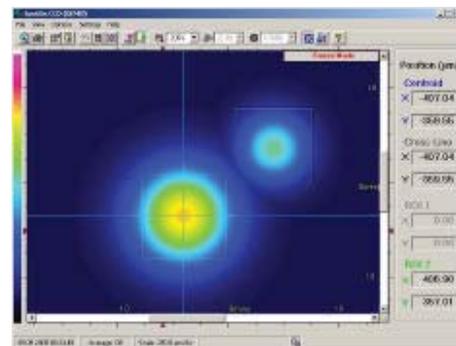


Fig. 10: CCD Image with two Centroids

A second important set-up is used to measure the opto-mechanical stability of the ports beam axes with respect to the laser input port and with respect to mechanical references of the TRO Baseplate and ALADIN Optical Bench. The principle of the set-up is shown in Fig. 11. The most important parts are two glass plates (GP) that are partially reflective and partially semi-transparent. By electronic autocollimators (EAC) the alignment cubes (AC) mounted on the TRO baseplate are adjusted with their surfaces parallel to the glass plates. Using these generated optical references a laser can be fed into the TRO perpendicular to the GP. The adjusted exit port mirror reflects the laser beam. The angular difference between the input laser beam and the back-reflected laser beam can be measured with the shown CCD and the beamsplitter (BS).

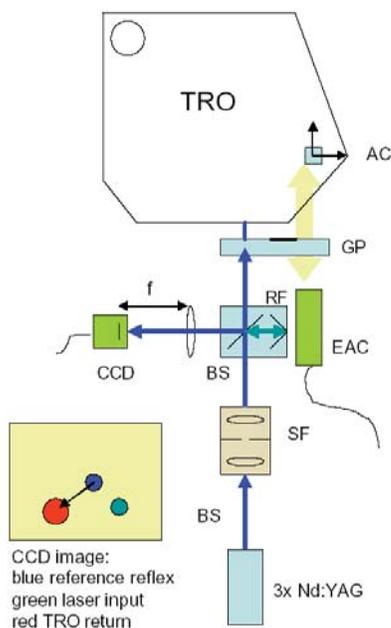


Fig. 11: Top View for Alignment of Laser



Fig. 12: Stability Measurement Set-up

The real set-up is shown in Fig. 12 and Fig. 13. The grey plate (dummy) in the middle of the picture represents the TRO. The glass plates and the EAC's can also be seen.



Fig. 13: Stability Measurement Set-up (side view)

7. SUMMARY

Specific technologies for the ALADIN TRO have been presented. Particular emphasis was put on selected gluing technologies, LIDT topics, and AIT processes. A major part of the design process was the development of a special tooling to transfer structural results to ZEMAX for stability analyses.

8. ABBREVIATIONS AND ACRONYMS

ADM-AEOLUS	ESA Wind Lidar Mission ⁽¹⁾
ALADIN	Lidar Instrument of ADM-AEOLUS
CTE	Coefficient of Thermal Expansion
FOV	Field of View
HWP	Half-Wave Plate
LAT	Lot Acceptance Test
LCM	Laser Chopper Mechanism
LIDT	Laser Induced Damage Threshold
QWP	Quarter-Wave Plate
TRO	Transmit-Receive Optics
ZEMAX	Commercial SW Tool for Optics Design and Analyses

9. REFERENCES

1. European Space Agency (ESA), *ESA's Wind Mission ADM-AEOLUS*, BR-235, 2005
2. Schmidt E., Mosebach H., Erdmann M., Camus F., *Simulation of the ALADIN Transmit-Receive Optics*, S.P.I.E. Proceedings Vol 5249, 2004.
3. Mosebach H., Erhard M., Camus F., *Aladin Transmit-Receive Optics (TRO): The Optical Interface between Laser, Telescope and Spectrometers*, S.P.I.E. Proceedings Vol 5962, 2005.

10. ACKNOWLEDGEMENTS

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