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HYPERIMAGE

A universal spectral imaging sensor platform for industry, agriculture, and autonomous driving.

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= Deliverable D2.2 =

Prototype of SWIR steering mirror

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Executive Summary

Application 1: Focus-tunable lens in a hyperspectral slit camera with NEO

After initial problems with the non-gravity-compensated EL, which caused significant drops in the MTF when being used with a horizontal optical axis, the newly developed technology of gravity compensation seems to have helped to overcome the problem. The EL-16-40-GTC-VIS prototype from Optotune, which has this new technology integrated, has been delivering promising results according to NEO.

Application 2: Focus-tunable lens in a lens objective for SWIR imaging in autonomous driving with SILIOS and ROBOTNIK

Based on the specifications for the autonomous driving case an electrical lens module (ELM), which combines an imaging optics with focus tunable lens for fast focus distance changes, could be identified. Testing needs to be performed at SILIOS. No results available yet.

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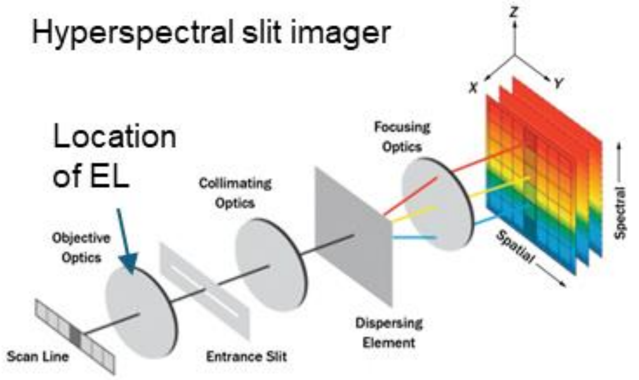
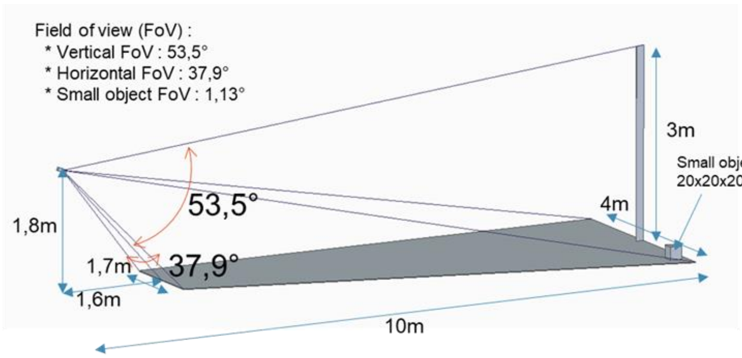
1. INTRODUCTION

A first goal is to develop an electrically tunable liquid lens (EL) with proper specs for clear aperture, tuning range, transmission spectrum, etc that can be used in the hyperspectral imaging applications of NEO for fast changes of the working distance. The development will require the definition and sourcing of the materials and antireflective coatings that can operate in the appropriate predefined wavelength range. Wavefront aberrations need to be minimized in order to maintain the critical image quality of the corresponding applications.



The EL shall be used in the front-lens configuration. To meet the specific requirements for demo 2.4 of NEO, a focal power range of 5 diopters (max 10 dpt) needs to be provided at an aperture diameter of approx. 15mm. The EL should transmit a large spectral range from VNIR 400nm to 1000nm and SWIR 1000nm to 2500nm.

A second application of the tunable lens technology is the autonomous driving concept developed by Robotnik and Silios. Silios considers to use a full tunable lens objective with integrated EL for the VIS-NIR part of this application for fast change of the working distance.




To meet the requirements the tunable lens objective needs to cover the spectral range from 420-870nm with a focal length of approx. 8mm and a field of view of 55.6x47.6deg.

More requirements will be defined by SILIOS for the SWIR side of the use case.

2. RESULTS AND DISCUSSION

Application 1: Focus-tunable lens in a hyperspectral slit camera with NEO

Samples of the Optotune liquid lens EL-16-40-TC-NIR were shipped to NEO for testing in two versions (5 dpt and 20 dpt focal power range).

Transmittance was measured up to 1700nm by Optotune. Measurements up to 2500nm were possible with the equipment available at NEO and the transmittance in this upper wavelength region was considered to be sufficient for the application.

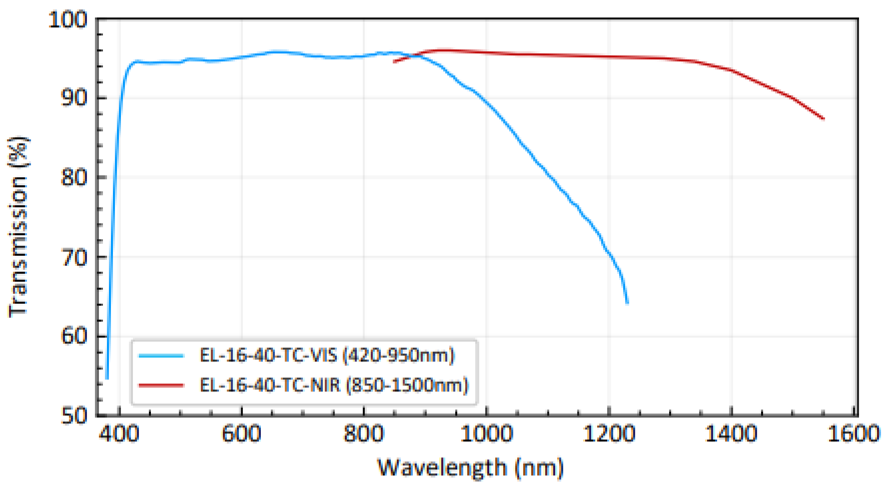


Fig 2.1: Transmittance of the EL-16-40-TC-NIR measured by Optotune

Testing of the EL-16-40-TC-NIR-5D at NEO has indicated some relevant drops in image quality. Analysis has shown the gravity-induced deformation of the soft membrane surface to be the root-cause if the lens is used with a horizontal optical axis. This effect called gravity coma is tolerable in many optical systems that do not react sensitively to it, yet it can lead to some decrease in image quality in other systems.

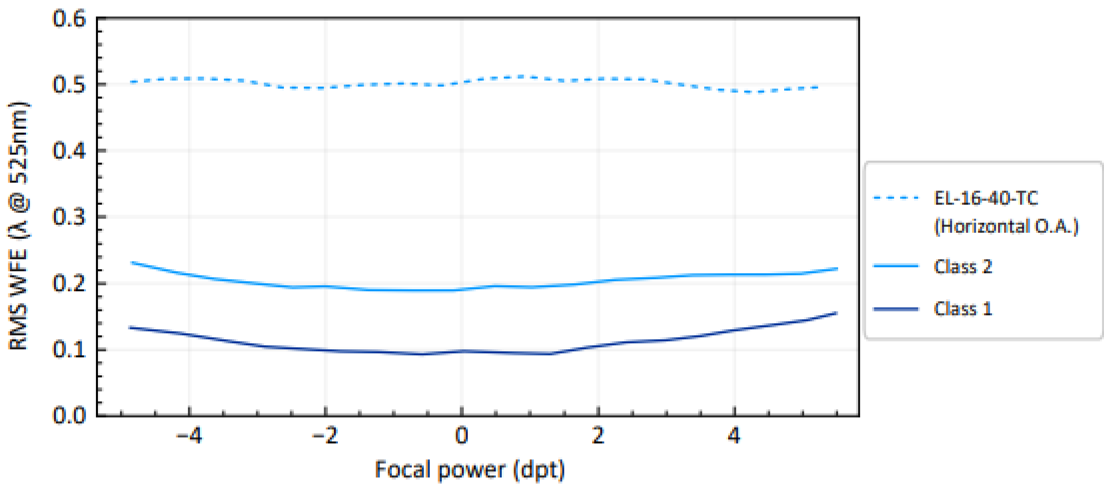


Fig. 2.2: The increase in the total wavefront aberrations through gravity coma when turning the liquid lens from a vertical to a horizontal optical axis can be seen between the solid lines and the dashed line.

The impact of gravity coma on the performance of an optical system can be simulated in Zemax. The implementation of measured optical wavefront aberrations in the optical model of the liquid lens and the corresponding simulations of the optical quality of the entire system is not straight forward. This is why Optotune has created a simulation guideline for NEO to investigate their experimental observations.

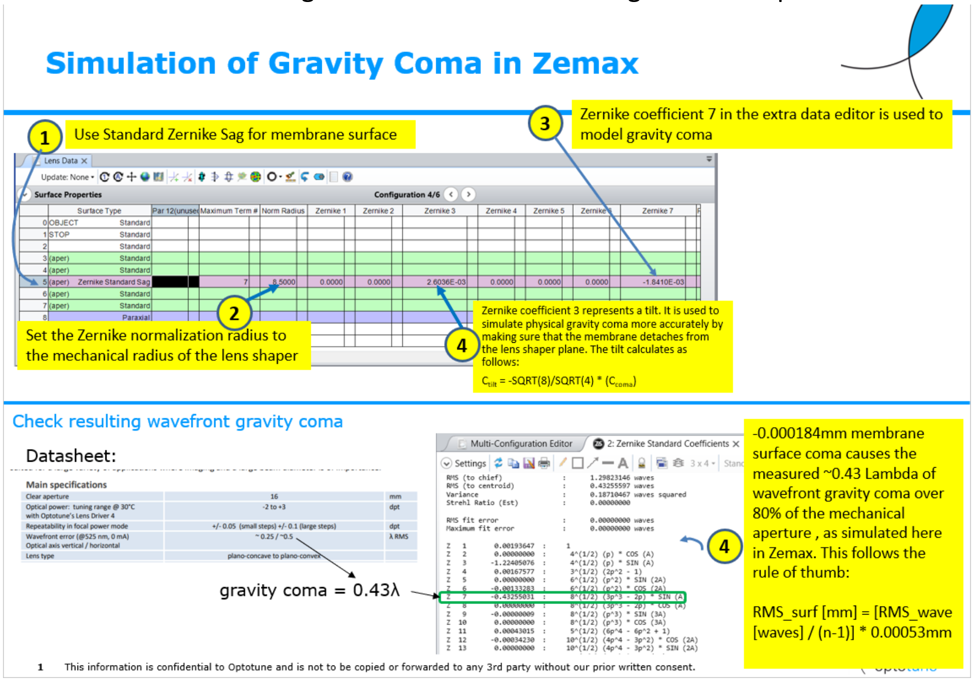


Fig. 2.3: Guidelines on how to model wavefront aberrations measured on an EL in Zemax.

Optotune is in the course of developing so called gravity-compensated liquid lenses. With a combination of two different liquids (of defined refractive index and density ratios) and two different membranes arranged in an internal and an external compartment gravity coma can be compensated internally in a passive way. The optical quality is the same indepentent of the posture of the EL. Optotune had shipped a prototype of such an EL-16-40-GTC-VIS to NEO for testing.

Fig 2.4: EL-16-40-GTC-VIS prototype with gravity-effect compensation.

The following test data of the EL shows that the posture-dependent gravity-induced effect could eliminated.

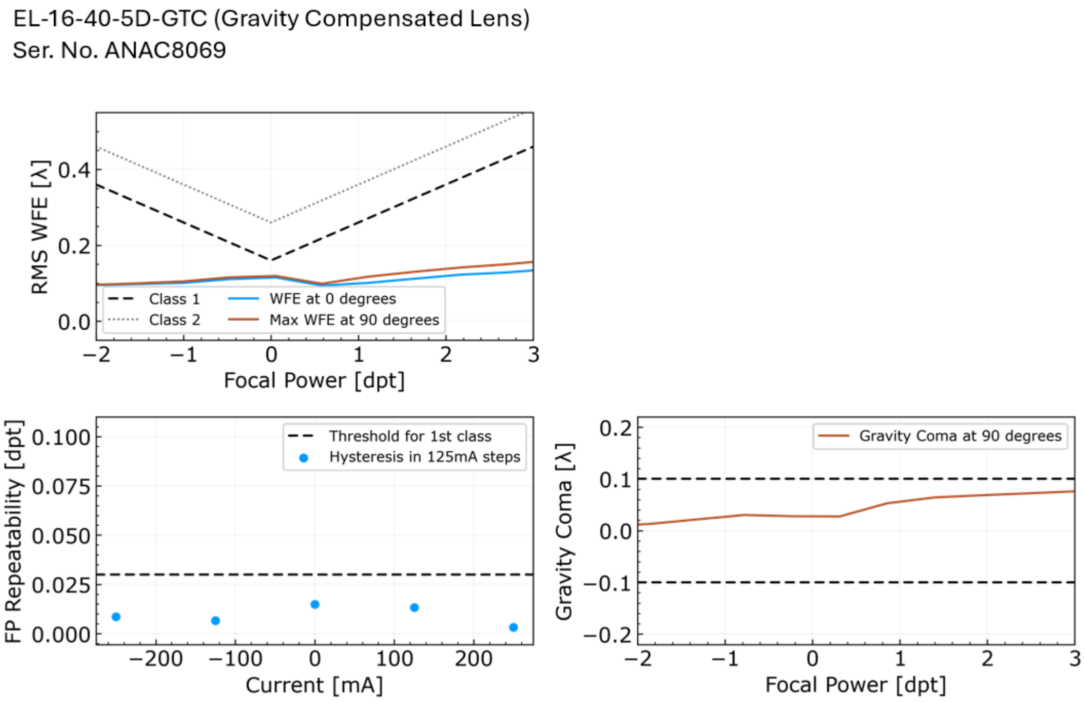


Fig. 2.5: Test data of the lens sample EL-16-40-GTC-VIS with gravity compensation sent to NEO. It can be seen that there is practically no difference between 0 degress and 90 degress orientation cases (top left) and the amount of gravity coma is close to zero over the entire focal power range (bottom right)

Further performance data of the EL-16-40-GTC-VIS prototype were assessed such as the response and settling time to an optimized step-input signal and the thermal focus drift of the lens. The settling time could be improved to roughly 13ms through the shaped input signal. The thermal focus drift depends on the focal power of the lens. It is about 0.025dpt/°C for focal powers around 0dpt, 0.034dpt/°C for -2dpt and 0.01dpt/°C at 4dpt.

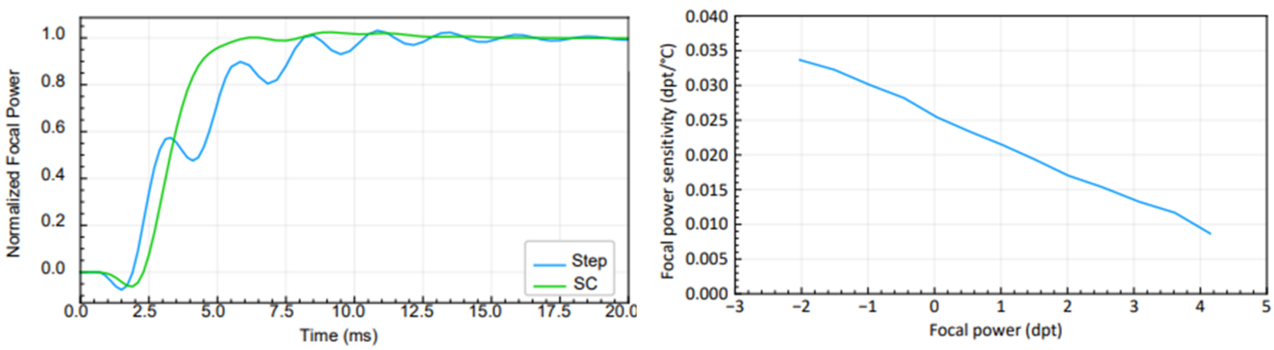


Fig. 2.6: Further test data of the EL-16-40-GTC-VIS prototype: Response and settling time (left), Thermal focus drift (right)

NEO has performed first tests with the EL-16-40-GTC-VIS prototype and has reported strongly improved results with this lens. The drop in MTF observed with a non-gravity-compensated lens could be avoided and image quality looks good. More details can be obtained from the report on work package 3.2.

Once the proper functionality of this EL type is reviewed and approved by NEO, Optotune will customize a version of this EL for NEO with optimized transmittance in the NIR range up to 2500nm.

Application 2: Focus-tunable lens in a lens objective for SWIR imaging in autonomous driving with SILIOS and ROBOTNIK

The objective of this application is to to use an ELM objective with a hyperspectral imager with a 4x4 color filter pattern for autonomous driving applications. The basic imaging requirements can be seen in the following illustration. The tunable lens objective needs to cover the spectral range from 420-870nm with a focal length of approx. 6-8mm and a field of view of 55.6x47.6deg.

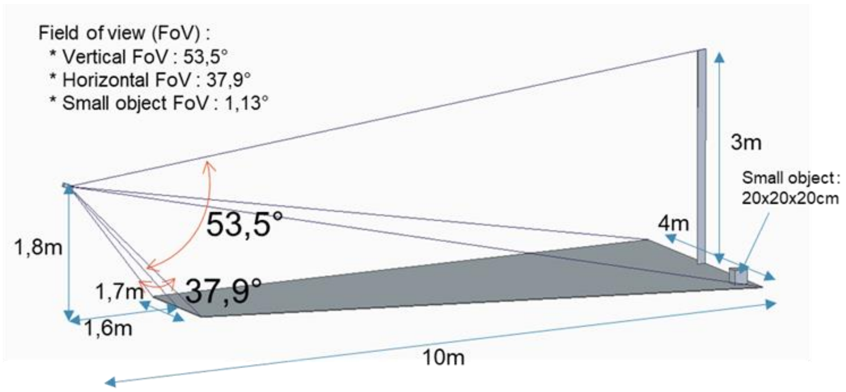


Fig. 2.7: Imaging requirements for autonomous driving application

Silios has further provided the image sensor specifications. A macropixel size of 13.8µm (3.45*4µm) had to be considered.

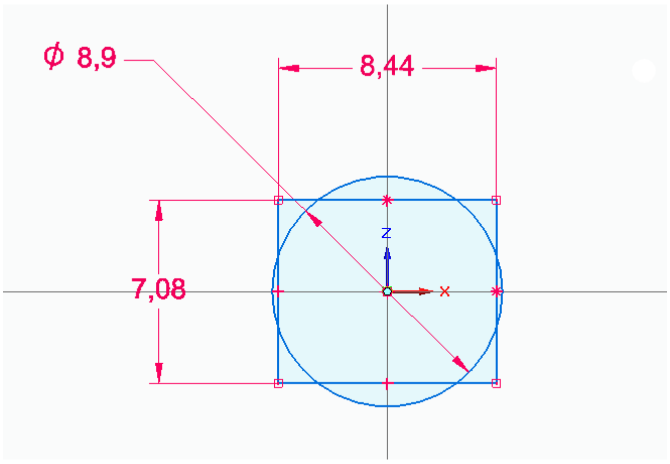


Fig 2.8: A scheme of the sensor and circle.

The existing electrical lens module ELM-6-5.6-9-C with an Optotune EL-3-10-VIS-26D liquid lens was identified as a promising candidate for the ROBOTNIK use case in the VIS-NIR range. This module is expected to support the wavelength range from 420 to 870nm.

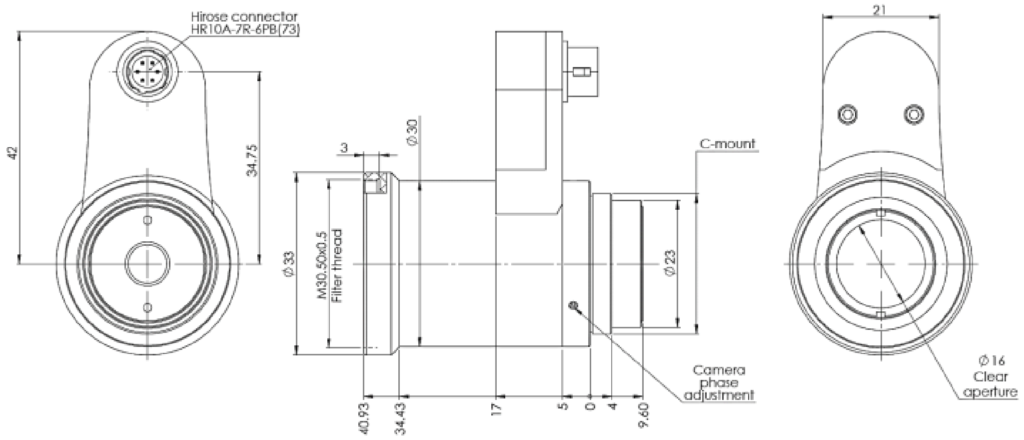


Fig. 2.9: Mechanical drawing of the ELM-6-5.6-9-C electrical lens module

A sample of this lens module was shipped to SILIOS along with controller and accessories. No test results are available yet.

3. CONCLUSIONS

Application 1: Focus-tunable lens in a hyperspectral slit camera with NEO

After initial problems with the non-gravity-compensated EL, which caused significant drops in the MTF when being used with a horizontal optical axis, the newly developed technology of gravity compensation seems to have helped to overcome the problem. The EL-16-40-GTC-VIS prototype from Optotune, which has this technology integrated, has been delivering promising results according to NEO.

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Based on the specifications for the autonomous driving case an electrical lens module (ELM) could be identified. Testing needs to be performed at SILIOS. No results available yet.

4. DEGREE OF PROGRESS

As part of WP 2.2 focus tunable lenses for two different applications of SWIR imaging have to be provided.

The afore described decision to switch from a non-gravity compensated liquid lens to a gravity-compensated prototype finally enabled the functionality planned by NEO. With this succesful change in the liquid lens design the functionality could now be met, whereas image quality was insuffient before.

A promising candidate for an electrical lens module was identified by SILIOS. A sample was sent to them for testing, and the characterization results are expected to be included in the upcoming report.

Based on the technical requirements outlined in WP1.1 and the updates provided in WP1.3, we resolved the main technical issue by developing novel gravity-compensated tunable lenses. According to this update, we consider the deliverable to be fully completed (100%).

5. DISSEMINATION LEVEL

Public