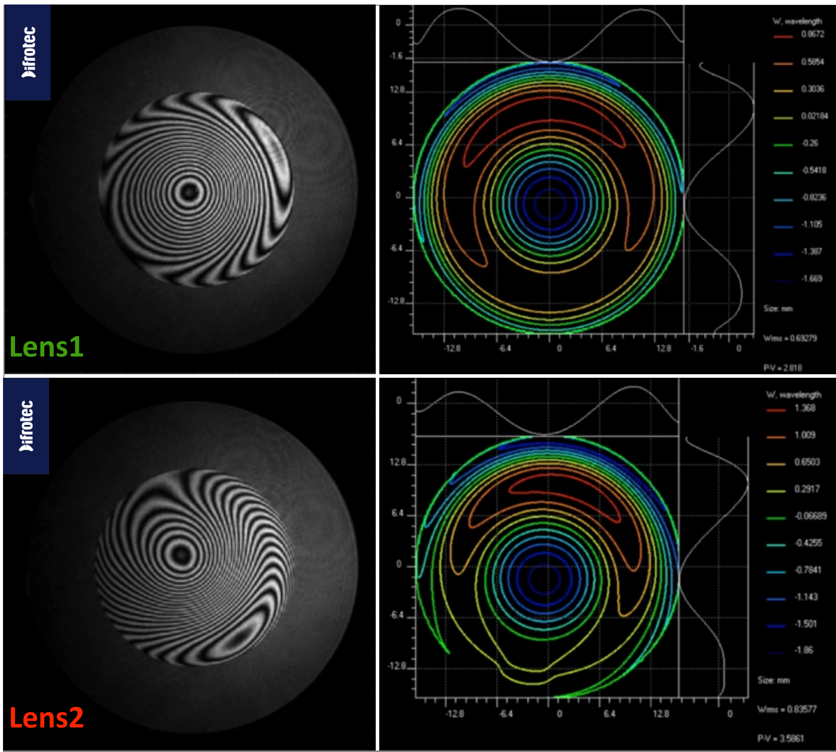
ESEO monitors the radiation environment & takes images from the orbit using an experimental telescopic space camera

Illustration: Taavi Torim

Difrotec helped enhance space camera's performance

Tartu Observatory with its partners developed the first onboard camera system for the European Student Earth Orbiter (ESEO).[1] ESEO is a microsatellite for monitoring the radiation environment and taking images of Earth from Low Earth Orbit (520 km). An experimental telescopic camera fitted onto it has Zeiss C Sonnar T* 1.5/50 lens with a resolution of about 25 m per pixel from the orbit.[2]

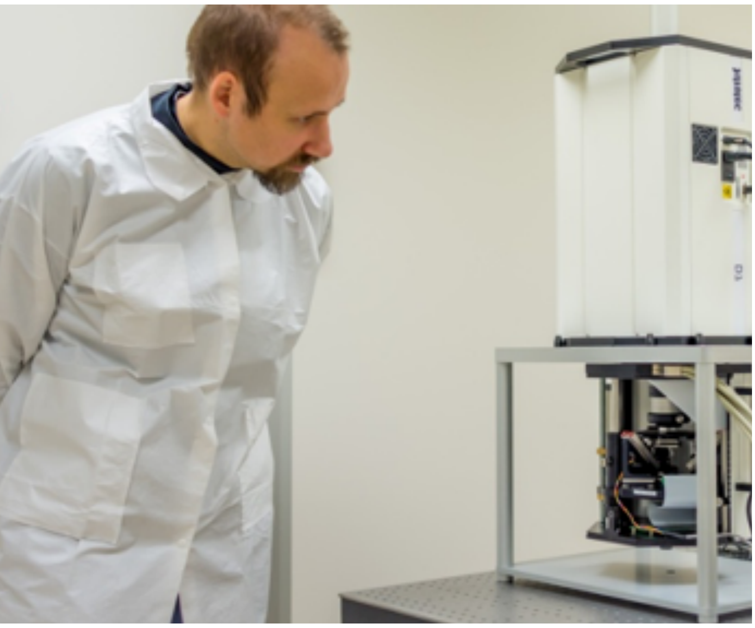
For the camera, Department of Space Technology in Tartu Observatory had two supposedly identical high quality lenses manufactured by **Carl Zeiss AG**: **Lens1** and **Lens2**. During the assembly of the telescopic camera with Lens2, it appeared that the image resolution had fallen significantly. Tartu Observatory contacted **Difrotec, a small Estonian company specialising in accurate surface form measurement and state-of-the-arts interferometry**. Difrotec had just the right equipment, D7 to compare the two Carl Zeiss lenses and characterise their image quality.



Fringe patterns & wavefront maps obtained from the lenses.

In general, photo lenses, such as **Zeiss C Sonnar T* 1.5/50**, have wave aberration peak_to_valley (P_V) up to 5 wavelengths.

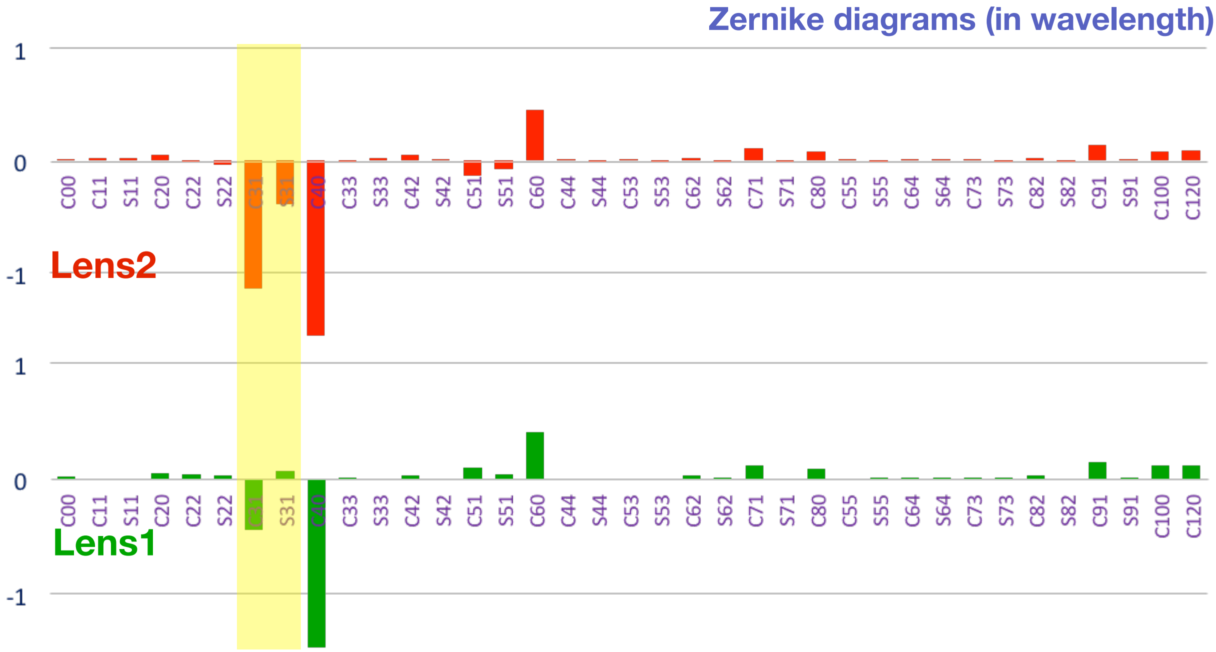
Large aberrations lead to increased wavefront gradients and consequently high density of fringes. Acquiring and processing such fringe patterns is as challenging as measuring aspheres. Here, **Difrotec's D7** with **DifroMetric** software proved itself uniquely useful.

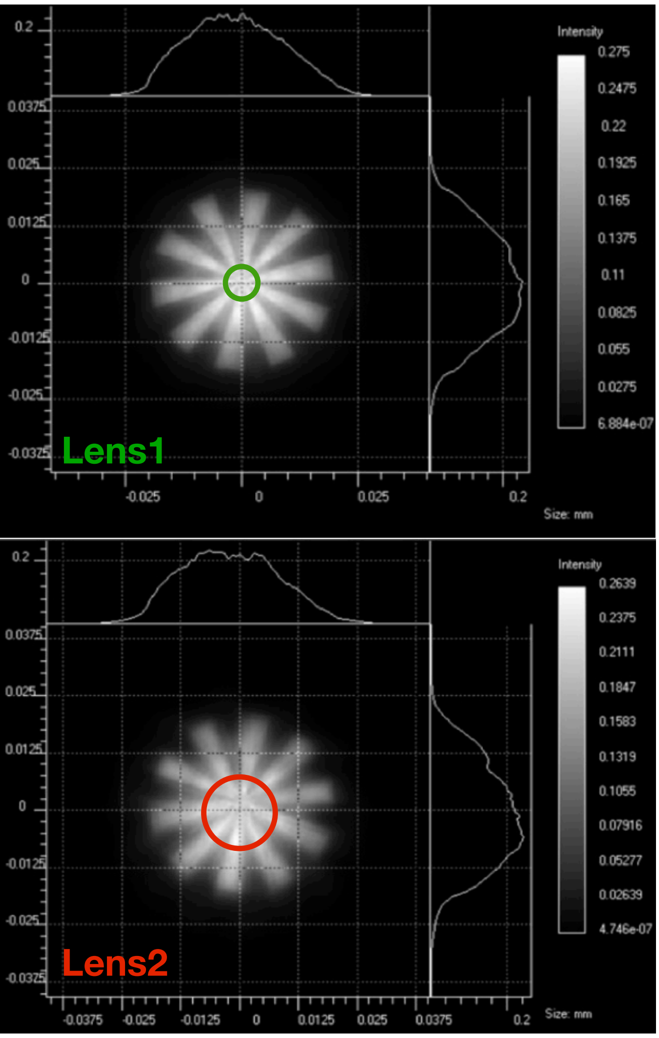


"The measurements done by Difrotec allowed us to fully characterize the ESEO telescopic camera optics and narrow down the issues we were experiencing with the latest revisions of the camera. For flight model assembly, Difrotec helped us to verify the quality of the flight lens before and after structural modifications."

- ***Henri Kuuste***, Engineer, Department of Space Technology, Tartu Observatory)

A tool that models optical systems, Zernike diagrams, shows that **Lens2** has an asymmetry, which is expressed by noticeable coma (C31, S31). Both lenses have approximately equal spherical aberration (C40 and C60). **Lens1** is relatively more symmetrical and therefore has significantly smaller coma (C31, S31, highlighted in yellow). Wavefront maps and Zernike





coefficients help evaluate lenses' general quality. For a complete analysis of their image quality, it is necessary to simulate images of test targets.

Simulated Siemens star target images help define the lenses' resolution. It is evaluated on the basis of acceptable minimum contrast 5% and chosen critical dimension (CD = 20 m). The radii of the marked circles (in red and green) give an estimate of resolution. From this, **we conclude that Lens1 resolves 20 meters per pixel, whereas Lens2 60 meters per pixel from the working distance of 520 km**. Namely, the supposedly identical replacement lens, Lens2, renders three times fewer details than the Lens1 and therefore does not match the required critical dimension.

The **unprecedented angstrom scale accuracy** of the D7 makes its capable of distinguishing the quality difference between lenses, where the aberrations far exceed (> 2400 times) the D7's accuracy. The interferometer **D7 with the software DifroMetric** offers a dynamic range wide enough to detect deviations of wavefronts in sub-nanometer and micrometer scale simultaneously.

Acknowledgements

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References:

1. https://www.to.ee

2. *Sünter et al.* Design and Testing of a Dual-Camera Payload for ESEO. 67th International Astronautical Congress, Guadalajara, Mexico, 2016.

3. *Slavinskis et al.* ESTCube-1 in Orbit: Experience and Lessons Learned. Aerospace and Electronic Systems Magazine, Vol. 30, No. 8, 2015, pp. 11-22.