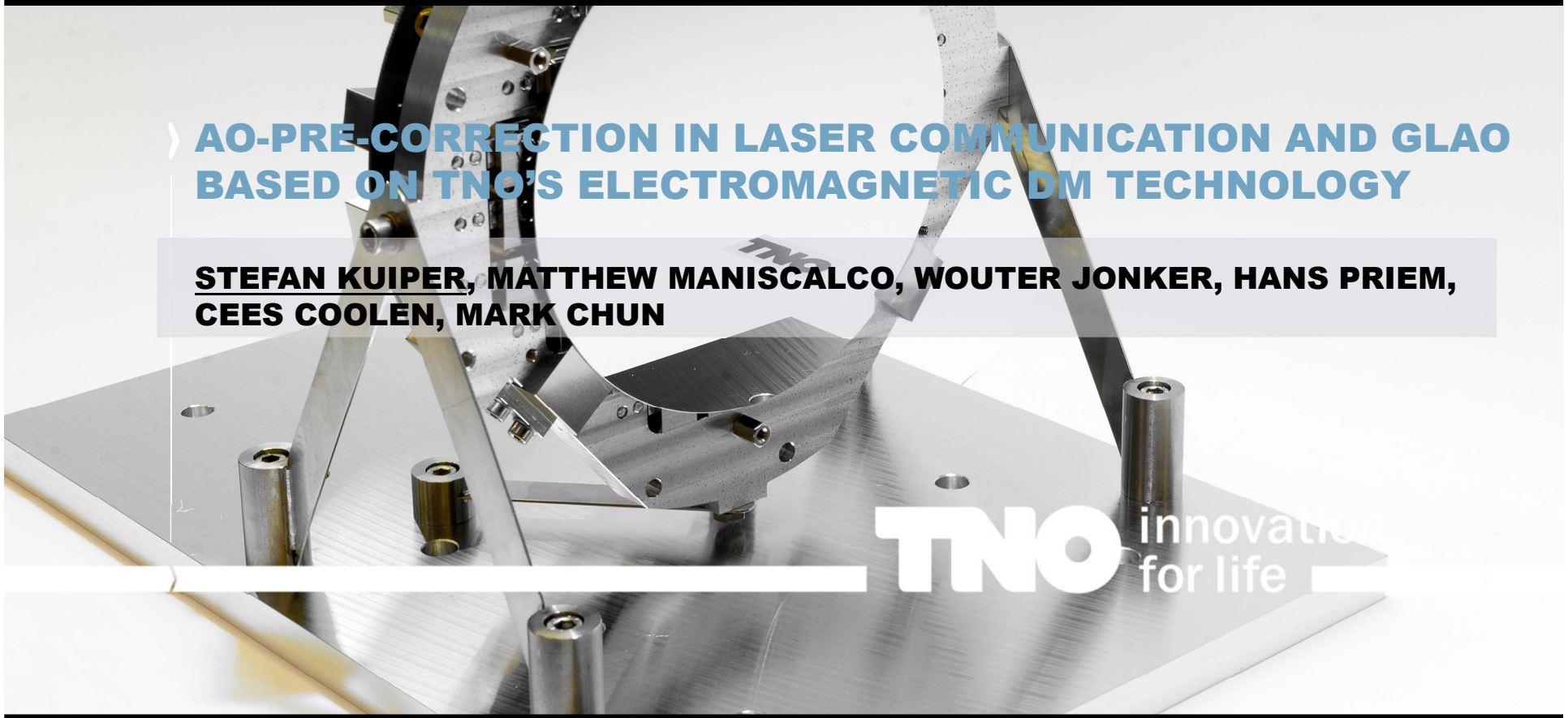


AO-PRE-CORRECTION IN LASER COMMUNICATION AND GLAO BASED ON TNO'S ELECTROMAGNETIC DM TECHNOLOGY

STEFAN KUIPER, MATTHEW MANISCALCO, WOUTER JONKER, HANS PRIEM, CEES COOLEN, MARK CHUN

TNO innovation for life

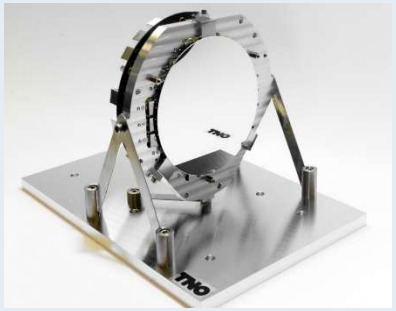
CONTENT

1) Introduction TNO
2) Applications; Laser-com and GLAO
3) DM-technology
4) Laser-com results
5) ASM for GLAO development
6) Outlook

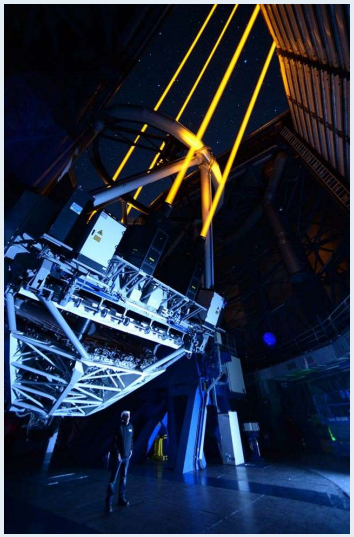
TNO'S EXPERIENCE WITH AO

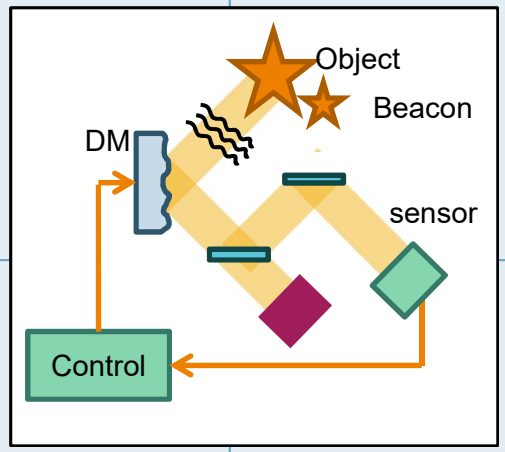
- Application fields; Ground based astronomy, Semiconductor, Laser Communication, and Space

Corrective elements

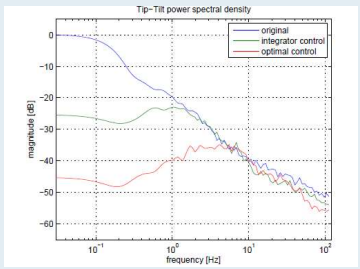


Beacon



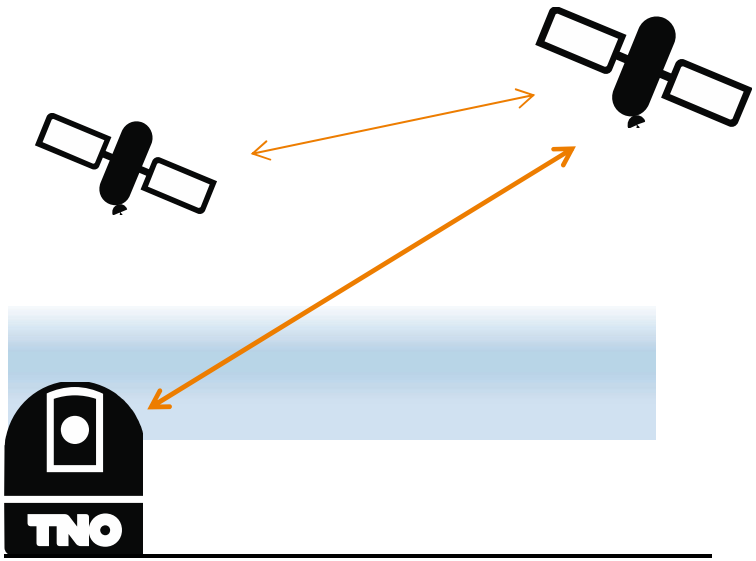


Control



Wave front sensing

LASER COMMUNICATIONS

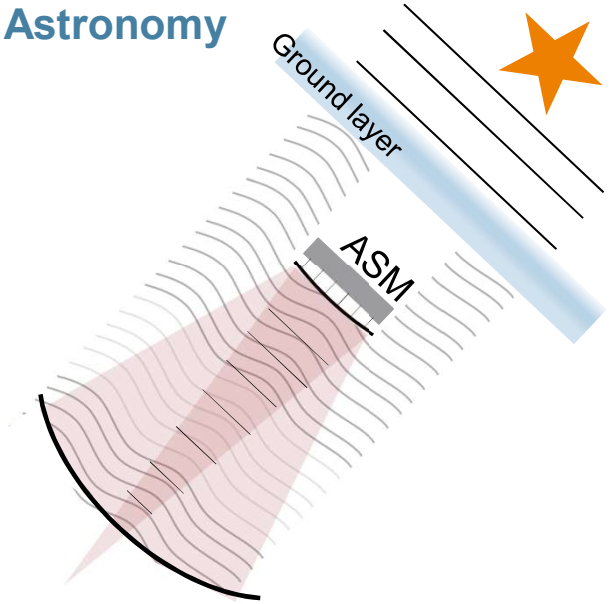


- **Key idea for AO-corrections:**

Increase data-throughput by pre-correcting the laser-beam for turbulence induces aberrations

Mostly driven by up-link performance

GLAO in Astronomy



Key Idea for AO:

Improve resolution over a wide field of view by compensating Ground layer aberrations.

Drivers for adaptive secondaries:

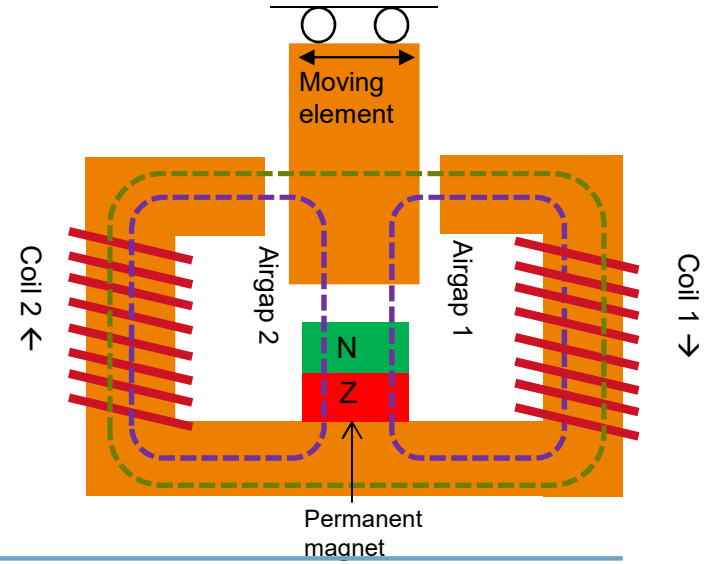
1. Wide field of view corrections
2. High-throughput and simplified optics
3. Minimize Thermal Background

- In both applications; **AO is an integral part of the overall system**
  - **Reliability and robustness** is of upmost importance to guarantee **availability**

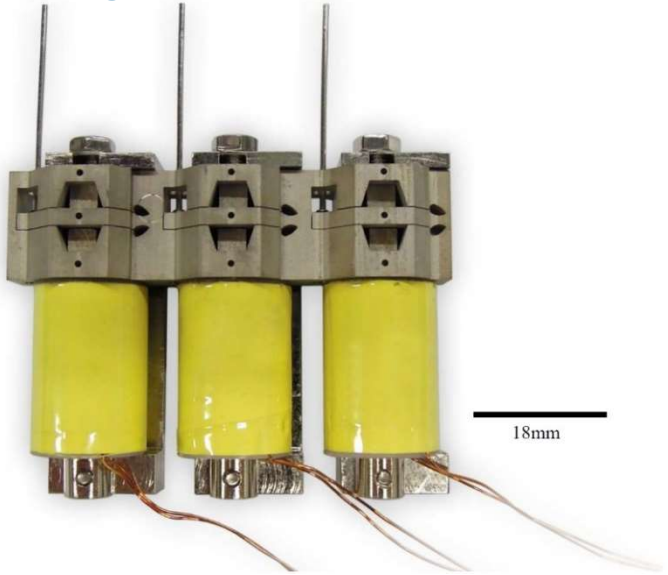
DM-TECH: ACTUATION

- Actuation principle; **hybrid variable reluctance**
- **High efficiency** in terms in volume and power
- Highly linear response (>99.5%)
- Efficiency; **38** $N/\sqrt{W}$

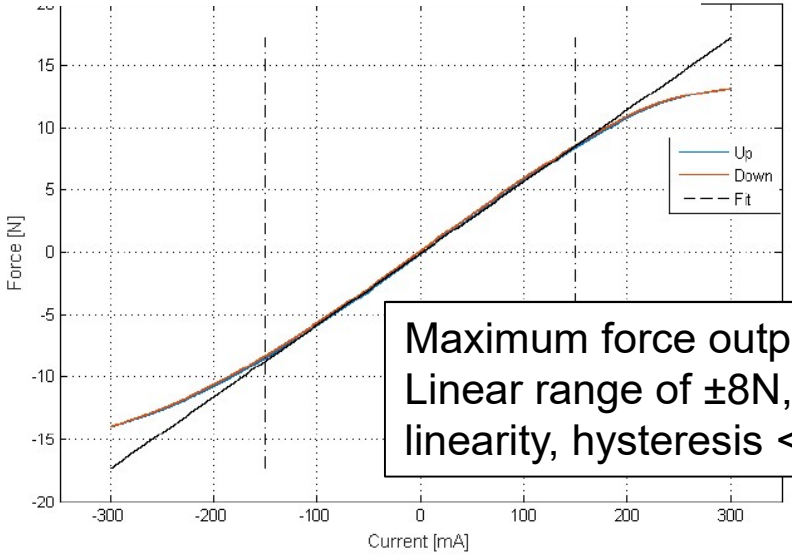
  ➔ ~40 times higher than a same size voice-coil



Prototype actuator strip



Test results: Force-Current

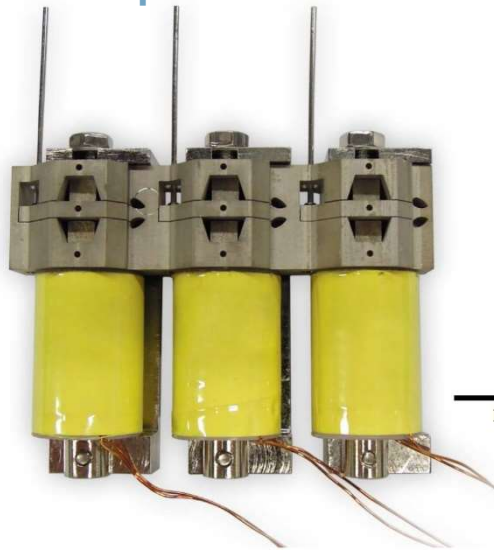


Maximum force output ± 14N
Linear range of ±8N, 99.5% linearity, hysteresis <1%.

TNO DM-TECH: MAIN ASSETS

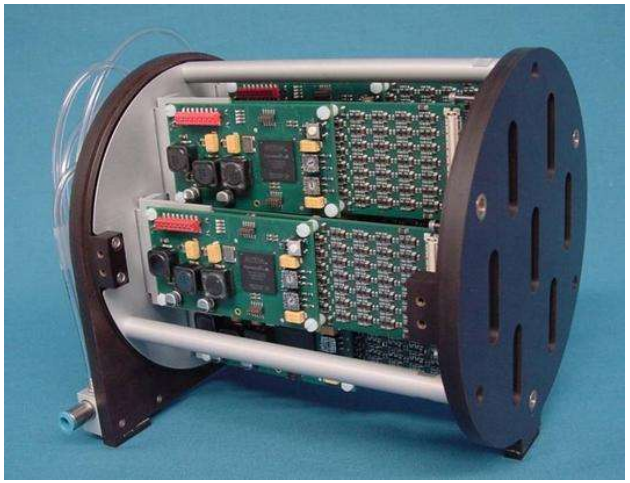
1. **High reliability** ; (i) No wear/aging, (ii) Compliancy (iii) redundant windings
2. **High linearity, repeatability and stability** (compatible with slow AO update rates)
3. **Low power dissipation** (~ few mWatts per actuator)
4. **Compact, low power electronics** (PWM)
5. **High force per volume;** Scalable to large apertures, and actuator pitches

18mm pitch actuators



4,3 mm pitch actuators

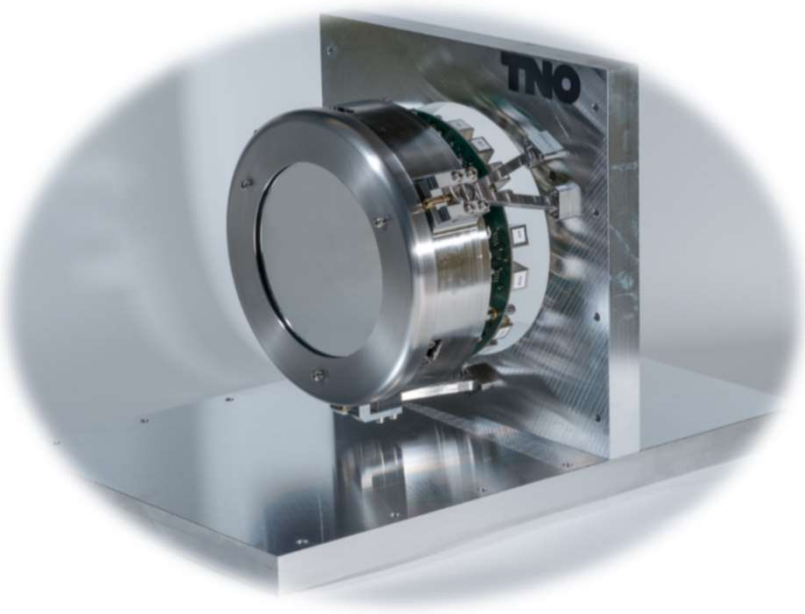
PWM drive electronics



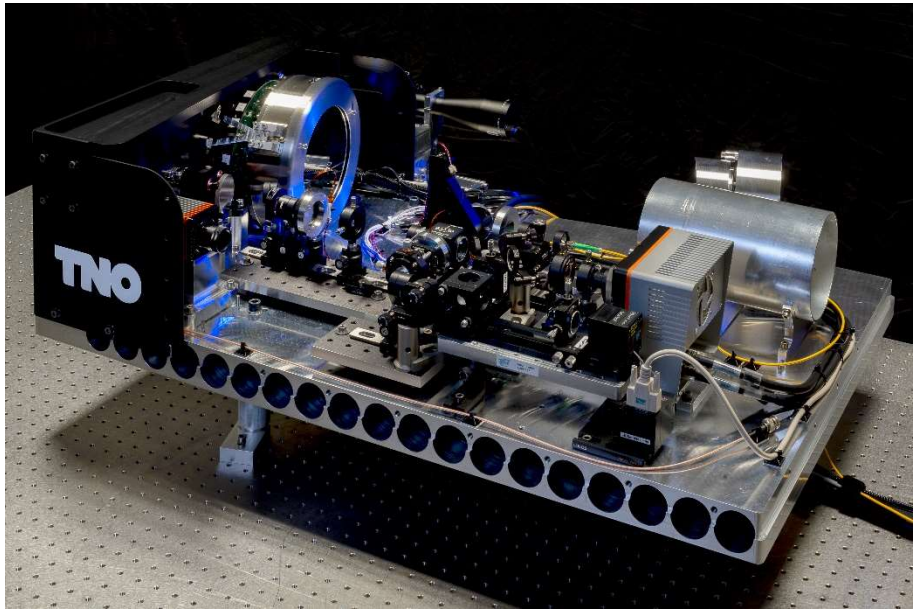
LASER COMMUNICATION

- **Ground terminal bread-board**
- **Goal:** Verify performance gain with AO and sensitivity for Point-Ahead Angle
- ESA Scylight program in cooperation with DLR
- Uses a 57-actuator DM by TNO

2nd DM proto (Commisioned April, 2018)

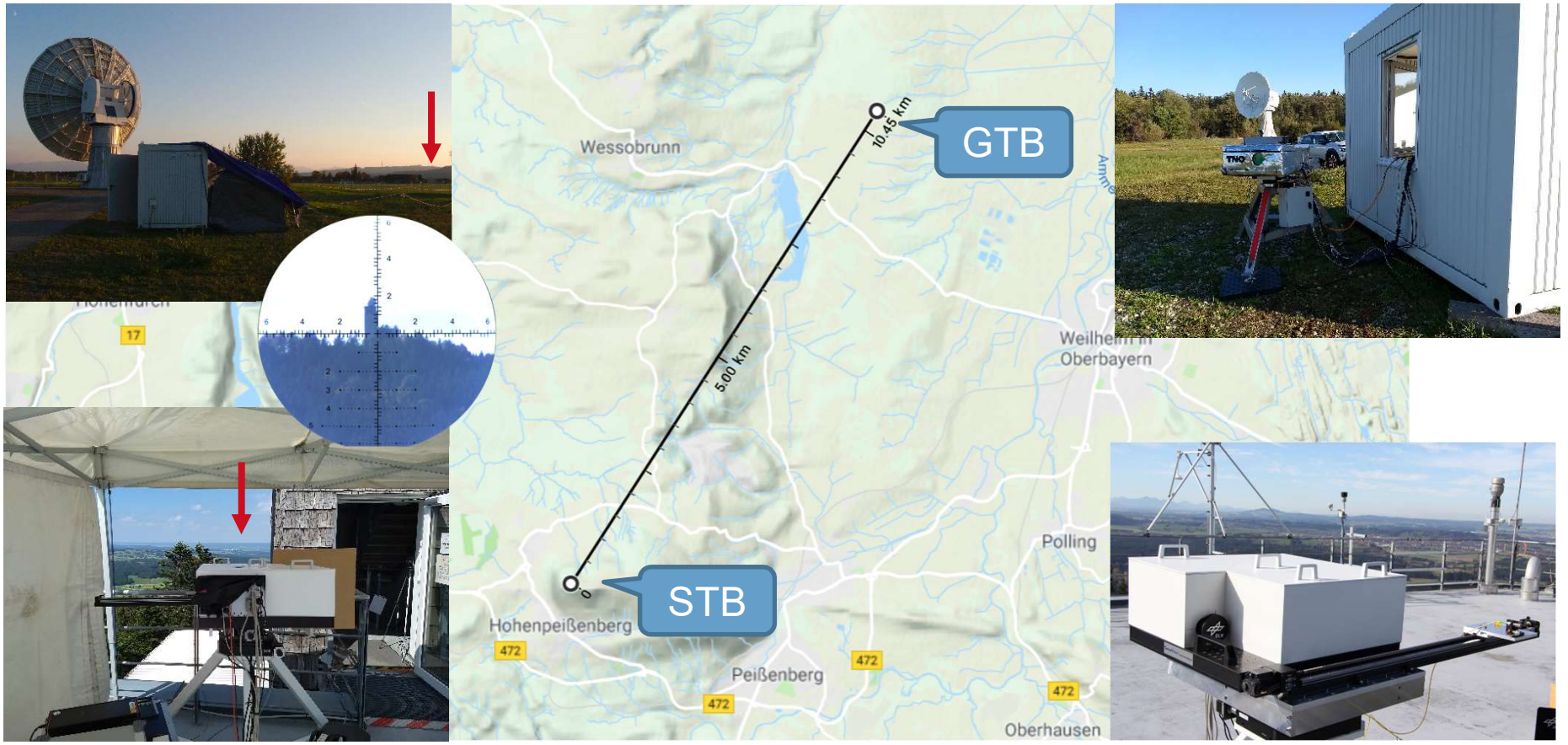


Ground terminal AO bench



10 KM TEST

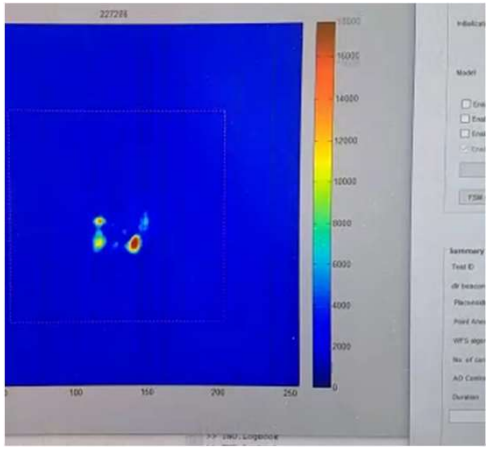
- 10 km ground to ground test in cooperation with DLR



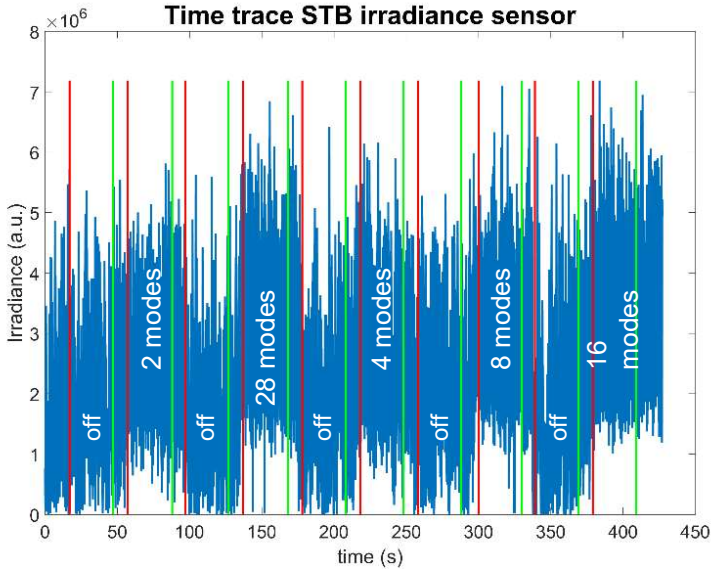
GROUND TEST RESULTS

- Link performance tested for different number of AO-modes and PA-Angles from 2 to 8μrads
- Maximum gain is **6dB** with 16 AO-modes corrected
- Hence, a improvement of the link performance by a factor of 4.
- Down-link improvement >20dB

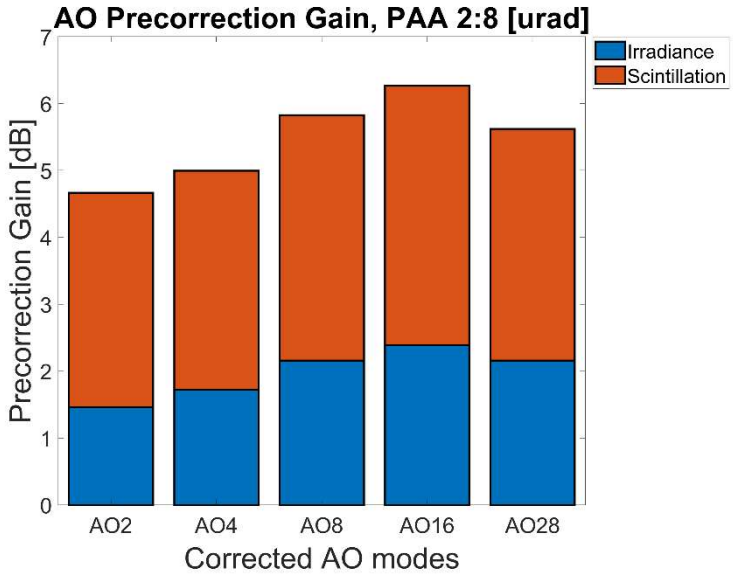
First results video



Raw data irradiance sensor



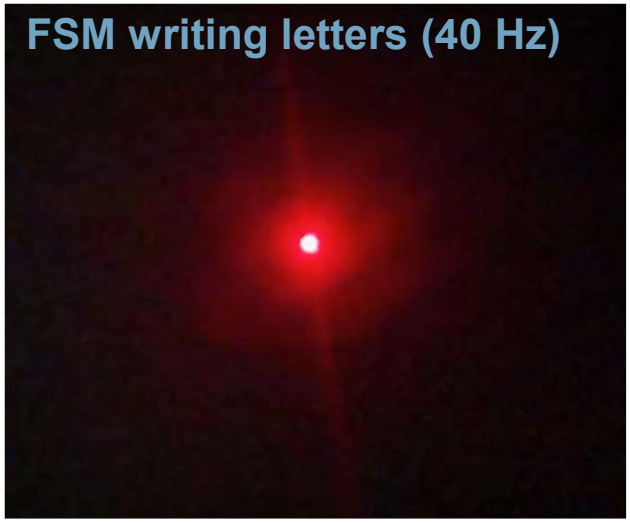
Performance gain



FSM FOR LASER-COMS

- Targeted for fast tip/tilt corrections and PAA on the **space segments**
- Utilized the same actuator technology (different configuration)
- Prototype successfully tested (July-2017)
- Currently going through industrialization phase with industrial partner Demcon

DEMCON

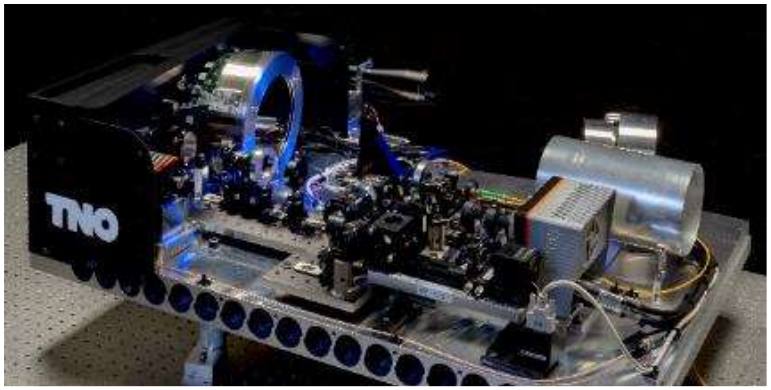


Main design Specifications	
Tip/tilt range	±2˚ (Optical)
Bandwidth (-3dB)	>1kHz
Jitter	< 1 µrads
Optical coating	Enhanced gold, >98% refl. @ 1550nm
Admissible Optical Power	~10Watts
Mirror diameter	Ø20mm
Volume	Ø24x30mm
Dependability	Redundant motor windings

FSM prototype

LASER COMS: NEXT STEPS

- Maturing AO- technology for feeder-links, including high power DM
- Realization of a AO-corrected Ground terminal in The Hague
- Collaboration with Airbus NL



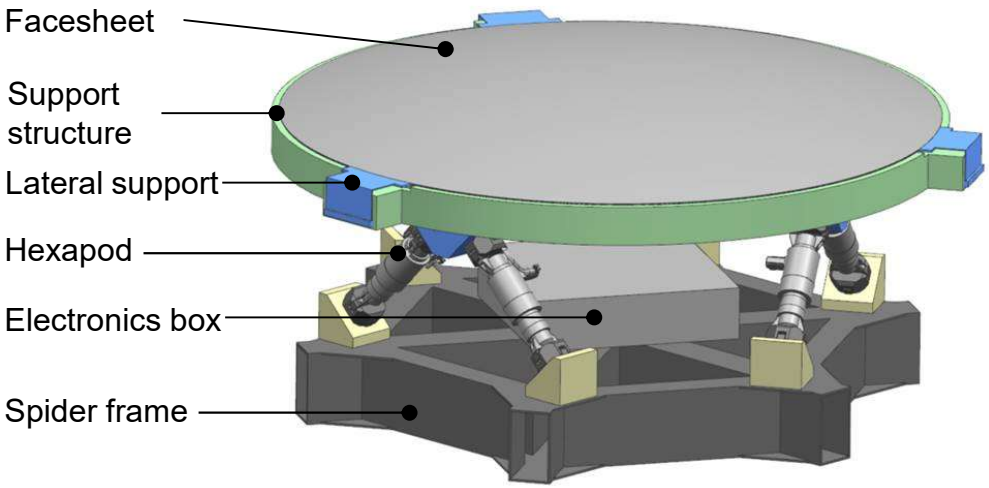
ASM DEVELOPMENT FOR GLAO

- TNO's DM technology highly suited for large adaptive secondary mirrors
- First feasibility study based on TMT requirements (**Ø3.04m**, **3462** actuators) shows potential;
- Key assets:
  - **Low power consumption**
  - **Low-complexity** by omitting internal feedback and liquid cooling.
  - **High compactness;** Within volume of passive M2, (retro-fitting)
  - **Inherently high reliability** (low complexity, free of wear/aging)

Concept design ASM for TMT

Specifications	
Mirror diameter	Ø3.04m (Convex)
Number of actuators	3462
Actuator pitch	50mm
Actuator stroke	26µm, Free stroke 8 µm, inter-actuator
Hysteresis	<1%
Actuator disipation	~12 W (3462 actuator)
Total dissipation	~300W (control boards)
Overall mass	~2.5 Tons

CAD model



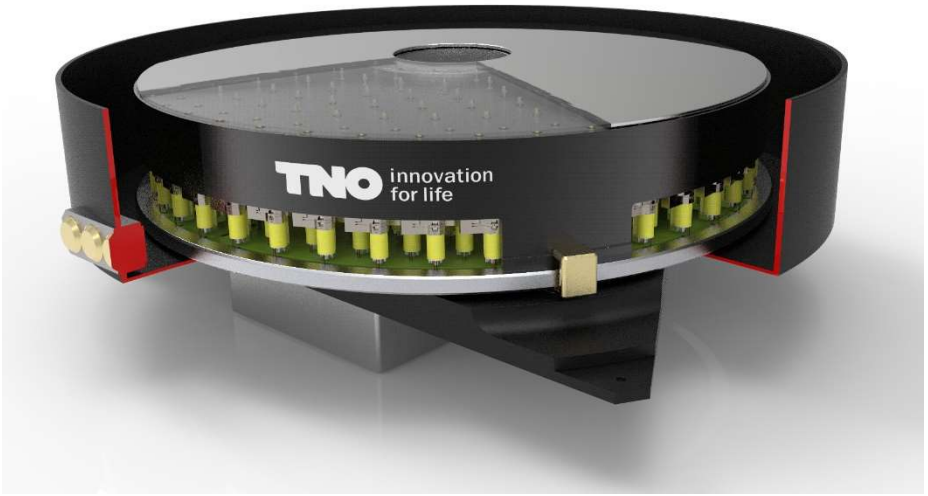
LAUNCHING PROJECT: ASM FOR UH-88

- First step: **ø63cm ASM** for the UH-88 telescope on Mauna Kea
- **Consortium partners:**
  - VDL ETG: actuators and integration
  - Harris: convex ULE face sheet
  - Hyperion; Drive electronics
- Status: PDR milestone reached May 2019. Target for installation in Hawaii end 2020

UH-88 ASM specifications

Specifications	
Mirror diameter	Ø630mm (Convex)
Number of actuators	204
Actuator pitch	40mm, radial
Actuator stroke	35µm, Free stroke 6 µm, inter-actuator
Hysteresis	<1%
Actuator disipation	~2.3 W (204 actuator)
Total dissipation	~20W (control boards)
Overall mass	~50kg

UH-88 ASM CAD render



CONCLUSIONS & OUTLOOK

- TNO developing AO-systems based on unique electromagnetic DM technology
- Significant progress in the fields Laser-coms and GLAO

ACKNOWLEDGEMENT