

可視赤外線観測装置技術ワークショップ 2025/11/10,11



ULTIMATE-START : すばる望遠鏡LTAOの 装置設置と光学調整について

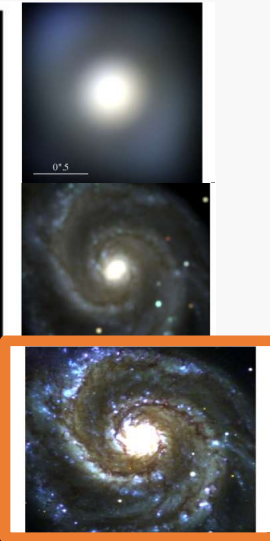
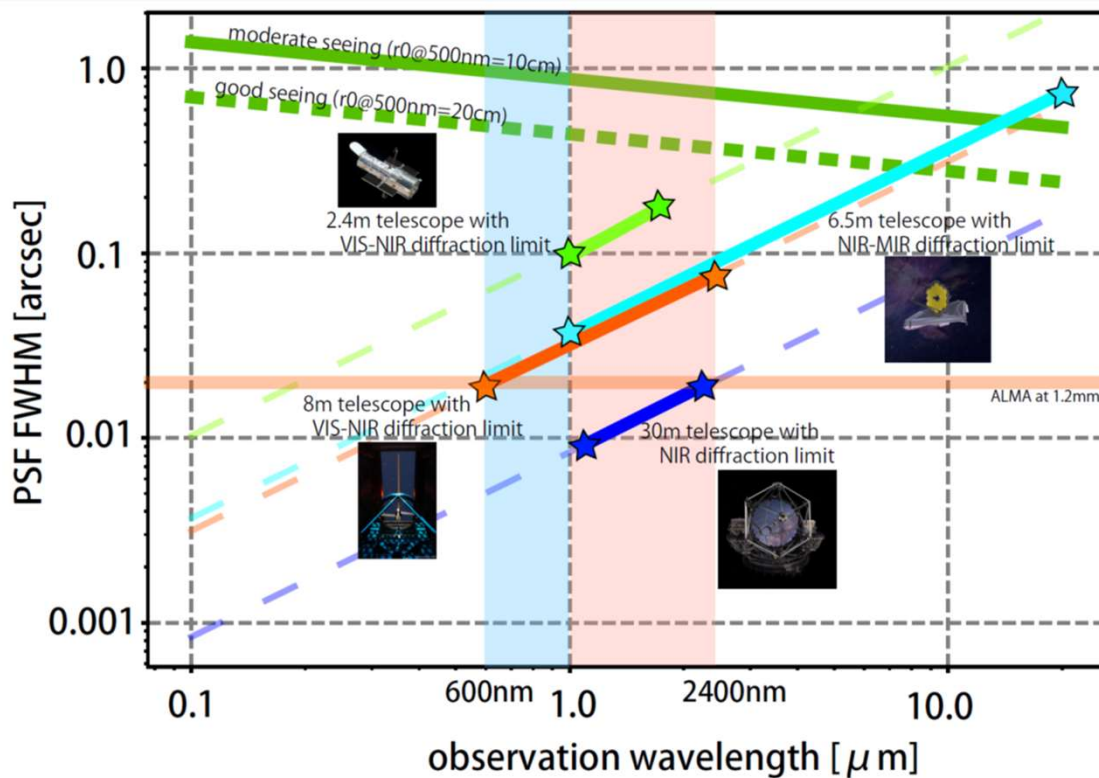
Aino Narayama, Masayuki Akiyama, Hiyori Tanabe, Mitsuaki Takahashi
(Tohoku University), Yosuke Minowa, Yoshito Ono, Koki Terao, Shin
Oya(NAOJ), Hajime Ogane, Jesse Cranney(ANU), Tomoyasu
Yamamuro(Optcraft)



What is the ULTIMATE-START Project?



The **ULTIMATE-START** project aims to implement **Laser Tomography Adaptive Optics (LTAO)** on the Subaru Telescope.



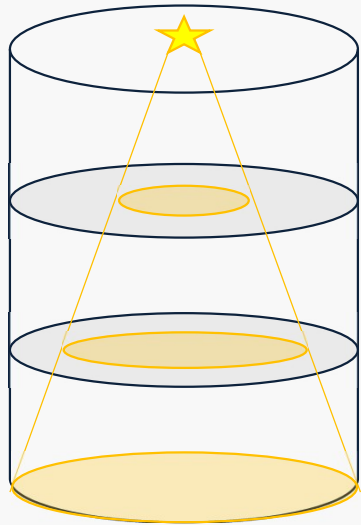
Goals :

- Achieve diffraction-limited performance in the **visible and near-infrared (NIR)** bands
- Attain a FWHM of **0.02 arcsec at 600 nm**
- Advance understanding of **galaxy formation and evolution**
 - Star formation
 - Galaxy mergers
 - The role of AGN feedback

What is LTAO?

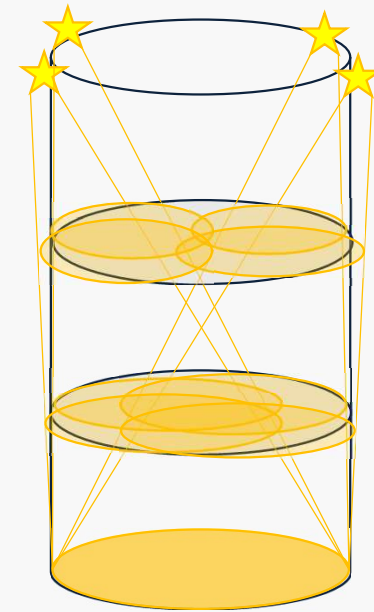
- **SCAO (Single Conjugate Adaptive Optics)**

- Uses **only one Laser Guide Star (LGS)**
- Due to the **cone effect**, there are regions where wavefronts cannot be measured, resulting in **reduced correction accuracy**



- **LTAO (Laser Tomography Adaptive Optics)**

- Uses **4 LGSs** to estimate wavefronts at various altitudes
- Reduces the cone effect and **improves AO correction performance**

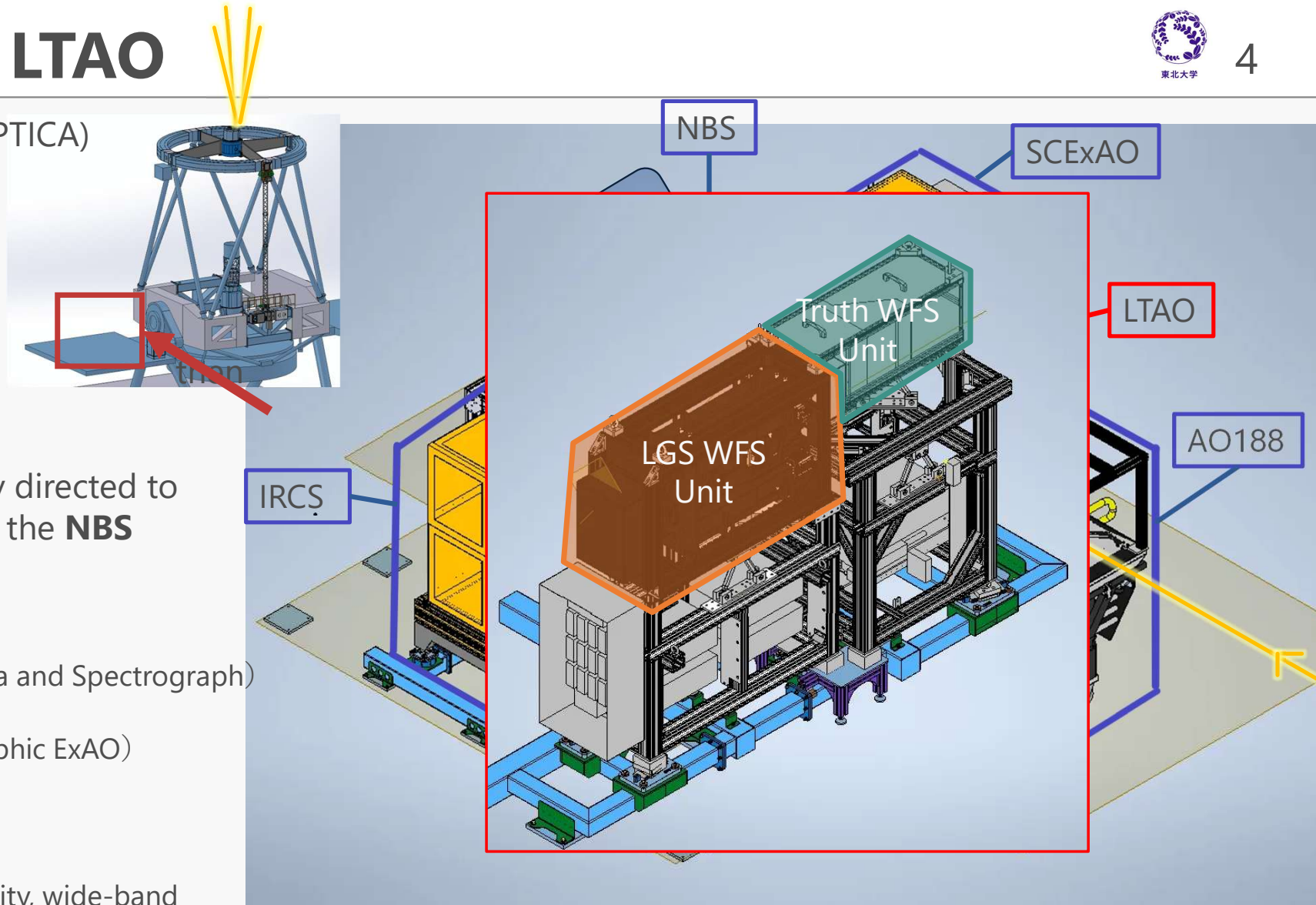


Overview of LTAO

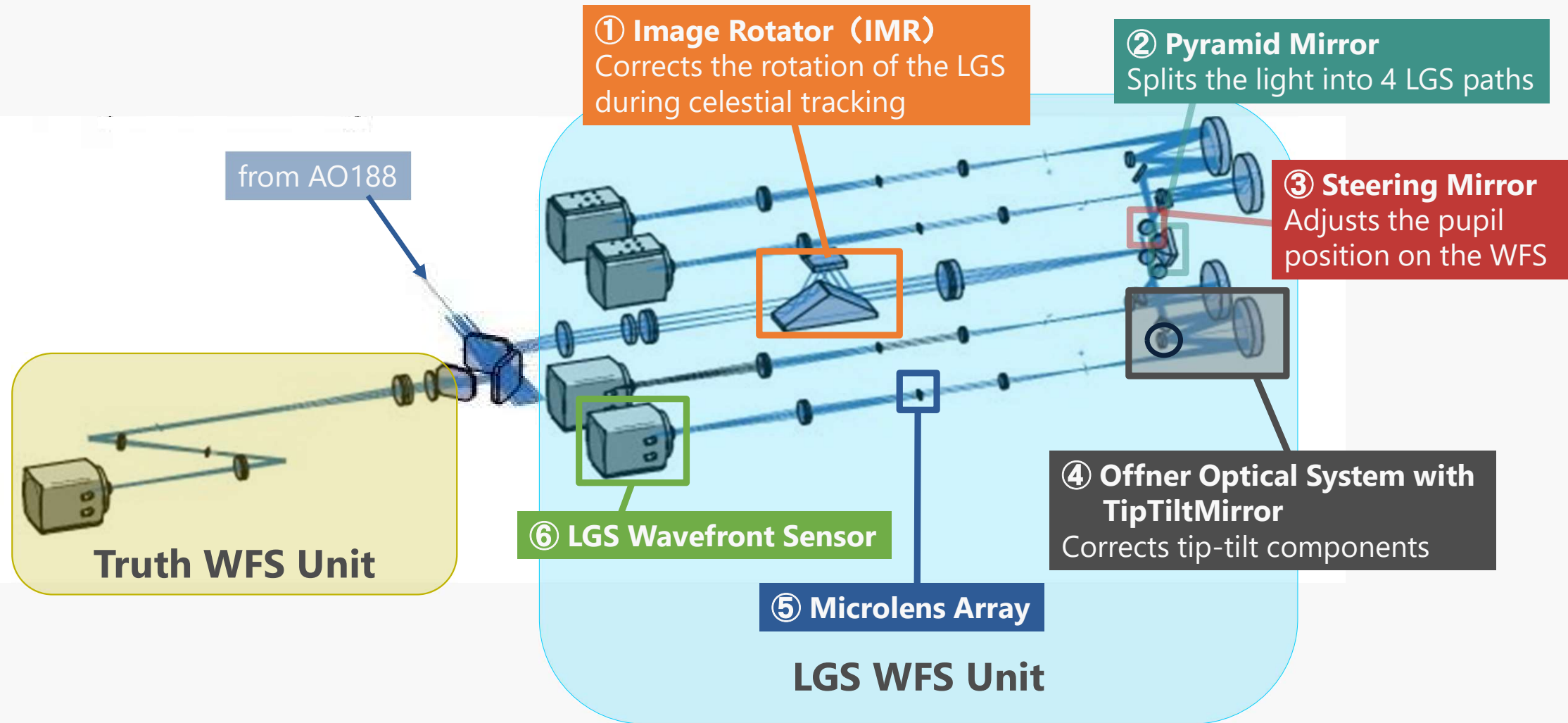
- **4 LGSs** (589nm, TOPTICA) are emitted (d=10"-40")
- Light from the telescope passes through **AO188**, through **LTAO**,
- And is subsequently directed to each instrument via the **NBS**

Instruments:

- **IRCS** (Infrared Camera and Spectrograph)
- **SCEXAO** (Coronagraphic ExAO)
- **3D II** (Visible IFU)
- **NINJA** (High-sensitivity, wide-band spectrograph)

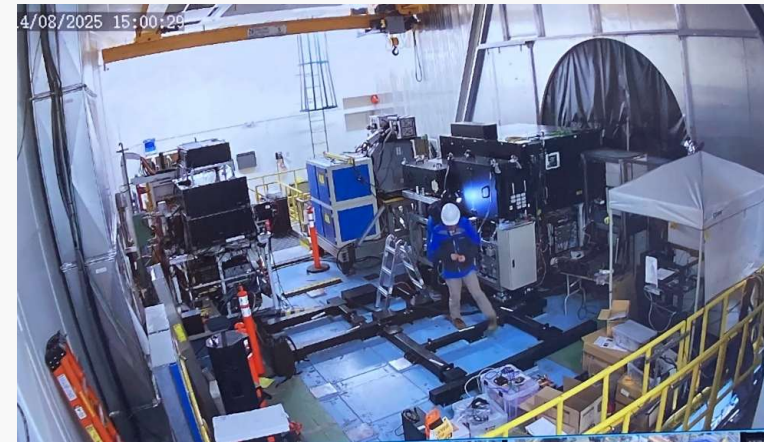


Structure of the LTAO WFS Unit

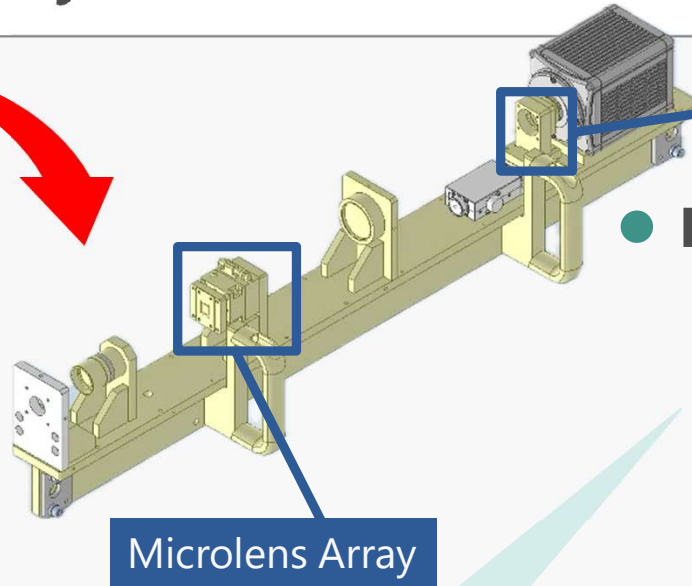
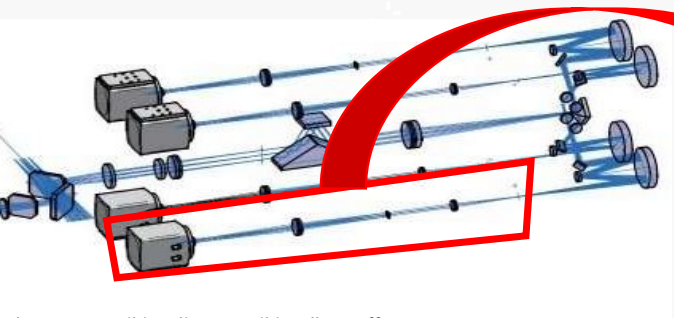


Installation Work Overview

- **Period: August 6–22, 2025**
- 1. Individual Optical System Adjustments**
 - ✓ Individual alignment of LGS SH-WFS
 - ✓ Leak test of the camera cooling system
 - ✓ IMR and focus adjustments
 - ✓ Offner optical system alignment
- 2. Installation and Alignment on the Common Platform**
 - ✓ Frame installation
 - ✓ Alignment using AO188 simulation light source
- 3. Tests**
 - ✓ Crane lifting test
 - ✓ Functionality check of sCMOS camera and Tip-Tilt controller
- 4. Fine Alignment and Data Acquisition**



Individual Optical System Adjustments - LGS WFS



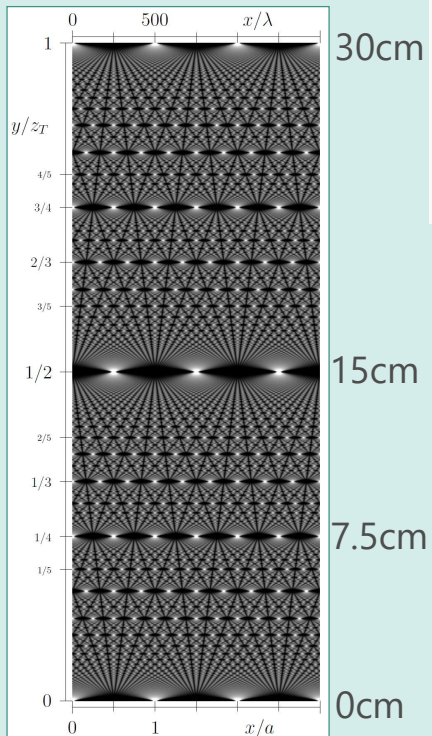
Lens Before WFS

Microlens Array

● LGS SH-WFS Adjustment

- The microlens array was centered
- Focus was adjusted by aligning the lens position. ← **Misaligned!**
- A later issue with vignetting (light clipping) was caused by this

https://en.wikipedia.org/wiki/Talbot_effect

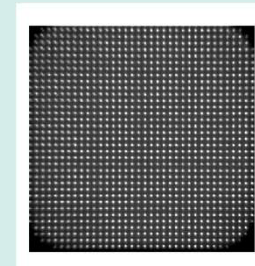


Due to Talbot effect ? :

When a plane wave is incident upon a periodic diffraction grating, the image of the grating is repeated at regular distances away from the grating plane.

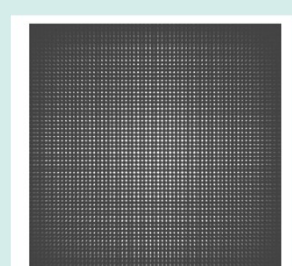
Image displacement: 15 cm
→ Lens displacement: 3.3 mm

Properly Aligned



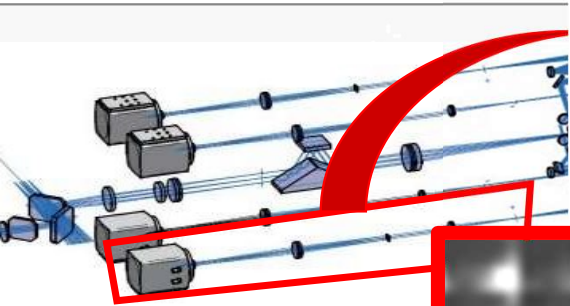
256 × 256 pix
32 × 32

Misaligned

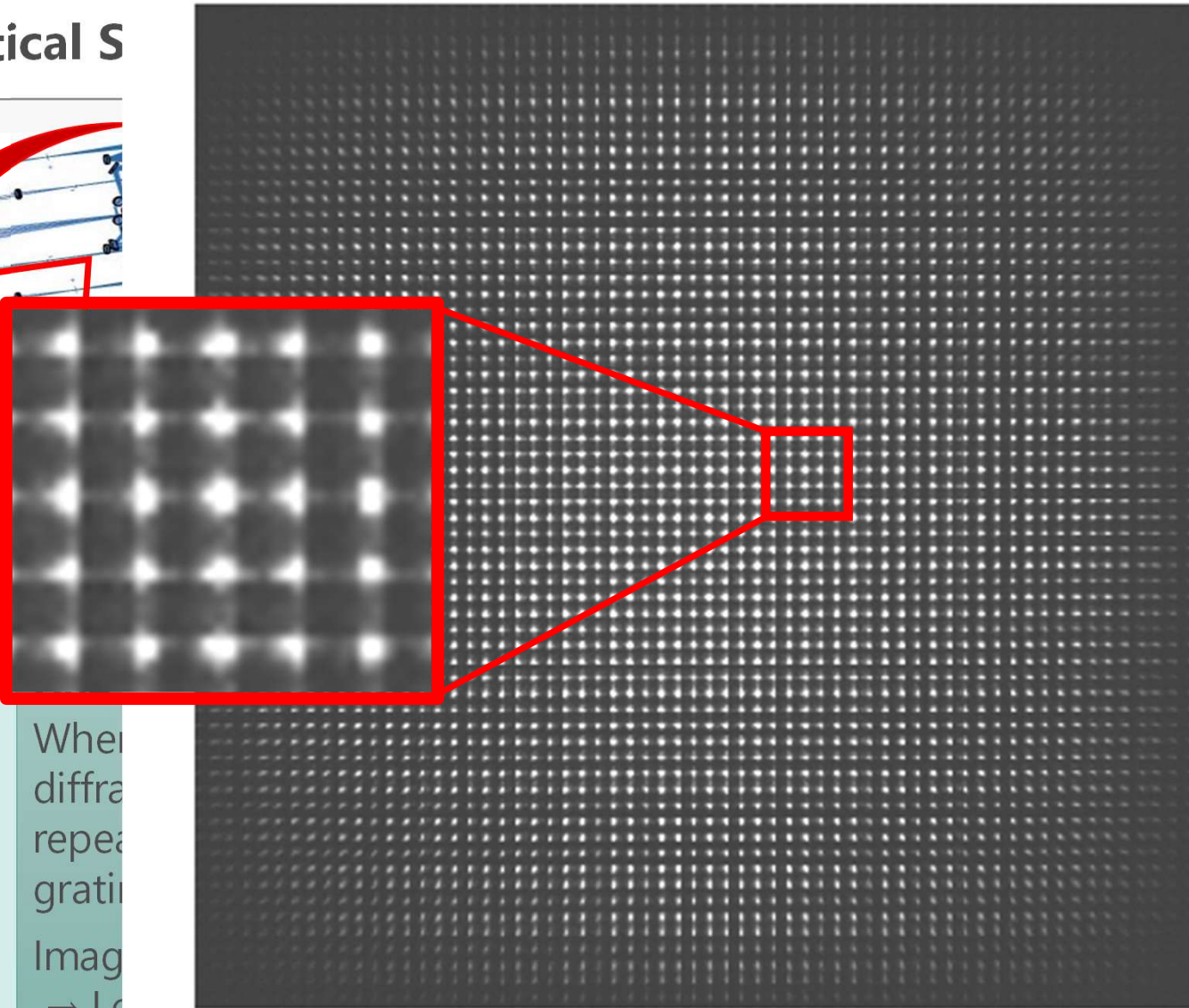
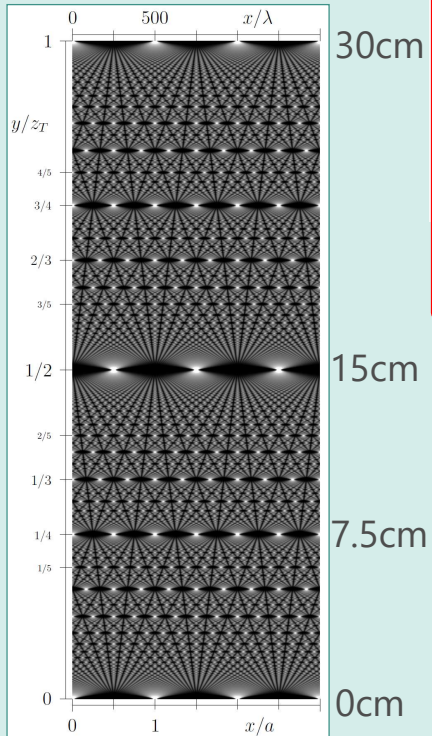


512 × 512 pix
64 × 64

Individual Optical S



https://en.wikipedia.org/wiki/Talbot_effect

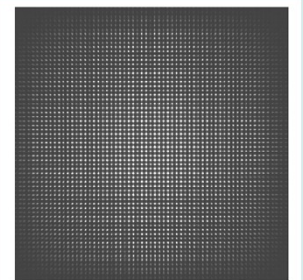


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Adjustment

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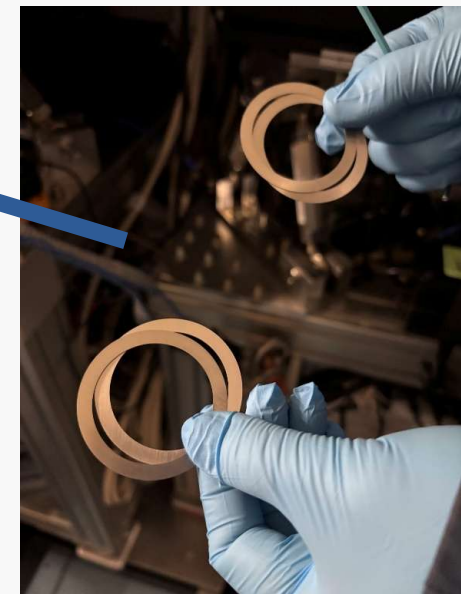


512 × 512 pix

Fine Alignment - LGS SH-WFS Vignetting Fix

● LGS SH-WFS Vignetting Fix

- **Vignetting** observed in LGS WFS after installation.
- Adjusted sCMOS camera position using screw hole play and **inserted shims** into some WFS units.
- Finally, the image of the microlens array **fits within the sCMOS camera area**.



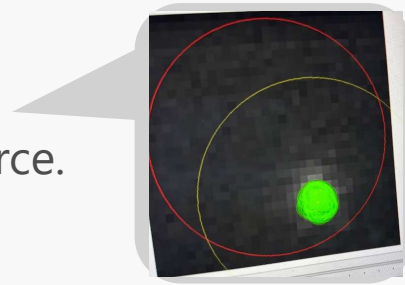
Fine Alignment - IMR Rotation Axis & Mirror Optimization



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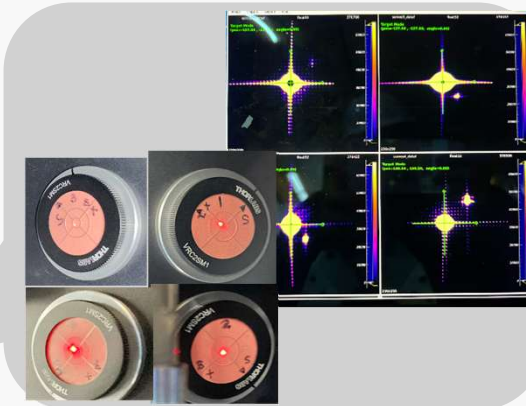
- **IMR Rotation Axis Adjustment**

Adjusted using hexapod with AO188 NGS light source.
Tracked to ~ 4 pixels on LGS monitor camera.



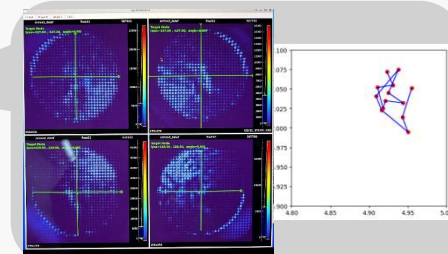
- **Z-axis Adjustment of Steering & Pyramid Mirrors**

Optimized using beam positions on WFS and sCMOS images.
Pyramid mirror Z-position set to **5.95 mm** (matches previous 5.75 mm).



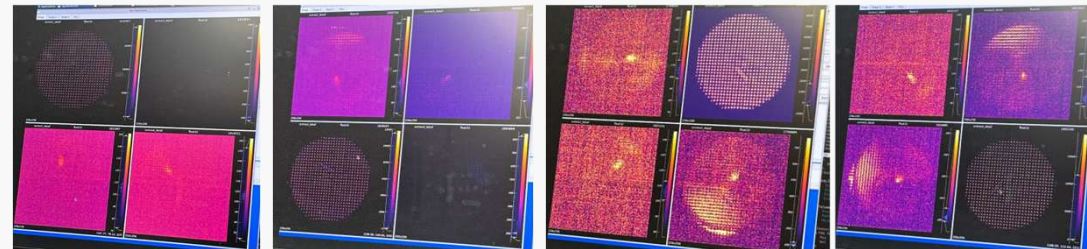
- **XY Alignment of Pyramid Mirror**

Rotated IMR in 30° steps, recorded positions splitting alignment source into 4.
Fixed at average position: **X = 4.93 mm, Y = 7.04 mm**.



- **WFS Image Check**

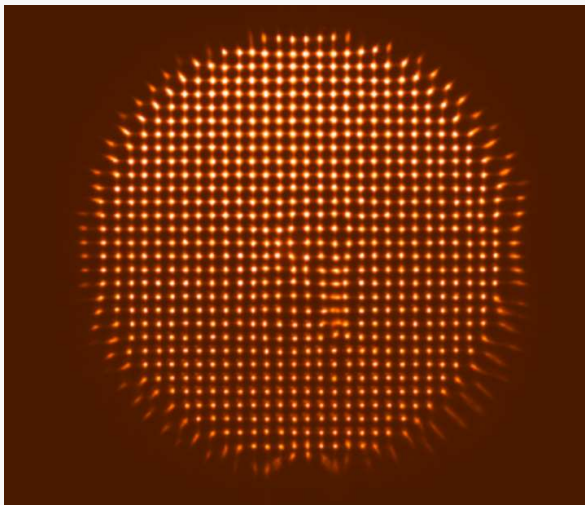
Confirmed proper light injection into each WFS.
Verified **32×32 sub-apertures** on all sensors.



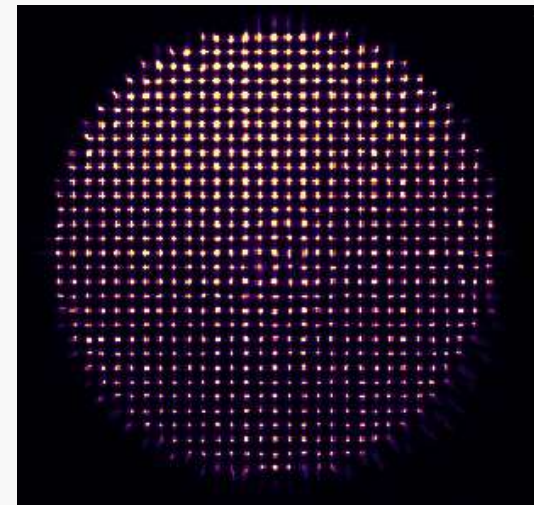
WFS images are distorted → Deformable Mirror is not flat enough

- **LTAO WFS:** Enough resolution and large dynamic range

Before flattening with LTAO WFS



After flattening with LTAO WFS



From Ono-san's slides of AO4ELT8

Future Schedule



- **LTAO WFS Unit Installation** : Summer 2025 (Completed)
- **LTAO Engineering Observation** : December 2025
- **Science Verification with IRCS** : 2026
- **Public Release as Instrument** : Earliest in late 2026
- **IFU 3D II Upgrade** : 2025–2027
- **NINJA Installation** : 2026

- **LTAO installation completed** in August 2025 as planned.
- **Remaining issues** : Astigmatism in **Offner 3**
- **Calibration and validation tasks** are still required to ensure optimal performance.
- **Next milestone**: Engineering observation scheduled for **December 2025**.



Thank you!