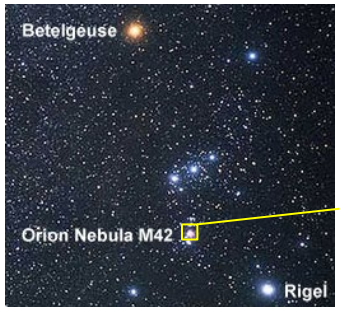
Adaptive Optics Development Activities at Advanced Technology Center

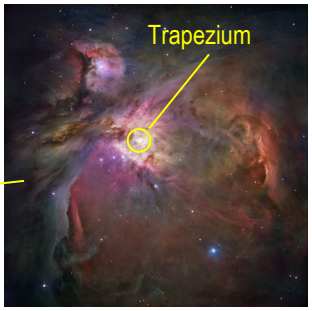
Shin Oya, Yosuke Minowa, Yoshito Ono, Masayuki Hattori, Koki Terao

National Astronomical Observatory of Japan

Images by Subaru Telescope

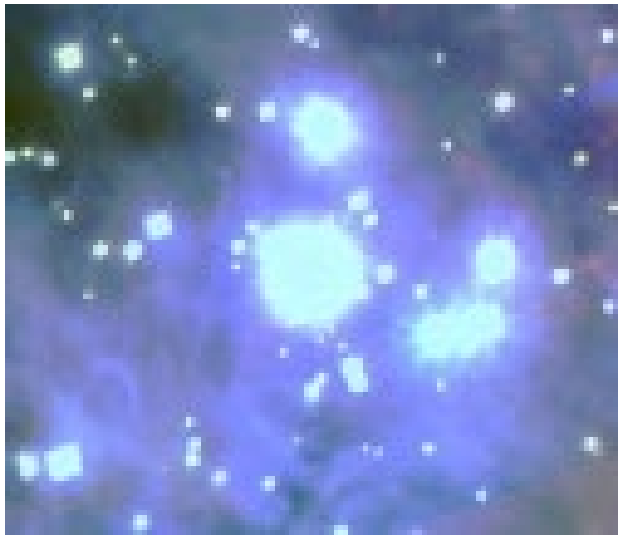
Orion Constellation



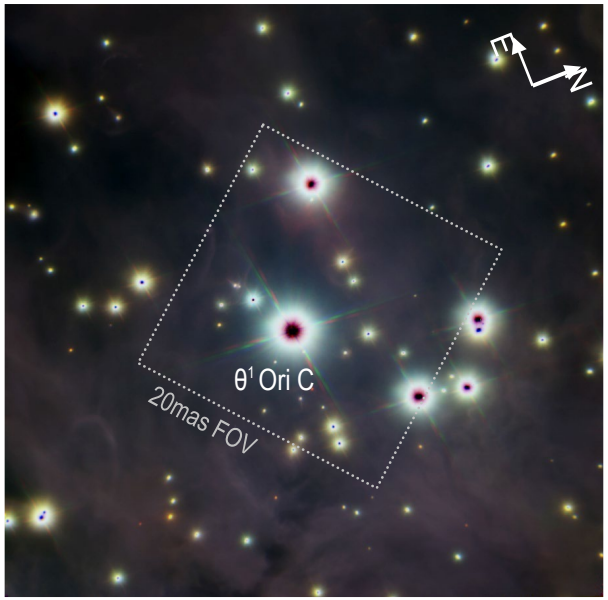


Orion Nebula (M42)

w/o Adaptive Optics correction of atmospheric turbulence
(@ Subaru first light)



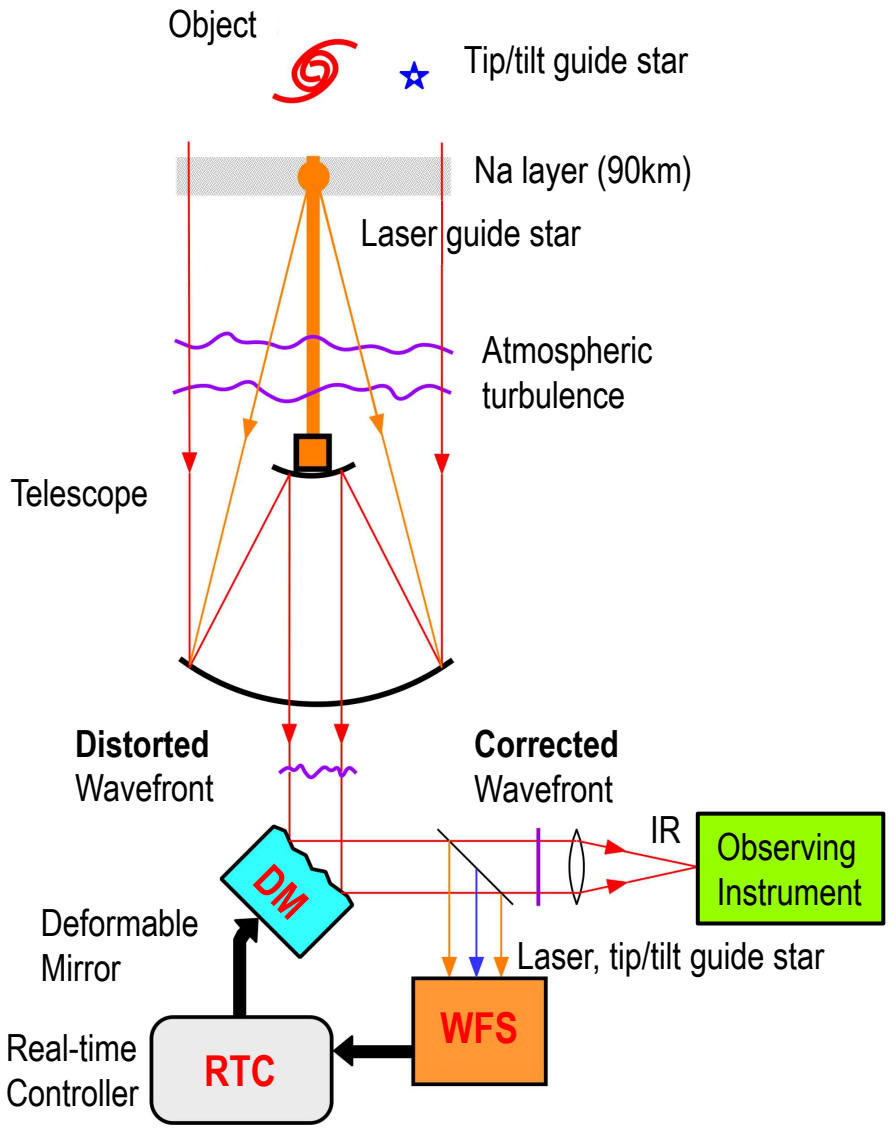
w/ Adaptive Optics correction



Trapezium star cluster in Orion nebula
Pseudo color of 3 infrared wavelengths (1.25um, 1.65um, 2.2um)

53 arcsec sq.

Adaptive Optics (**AO**)



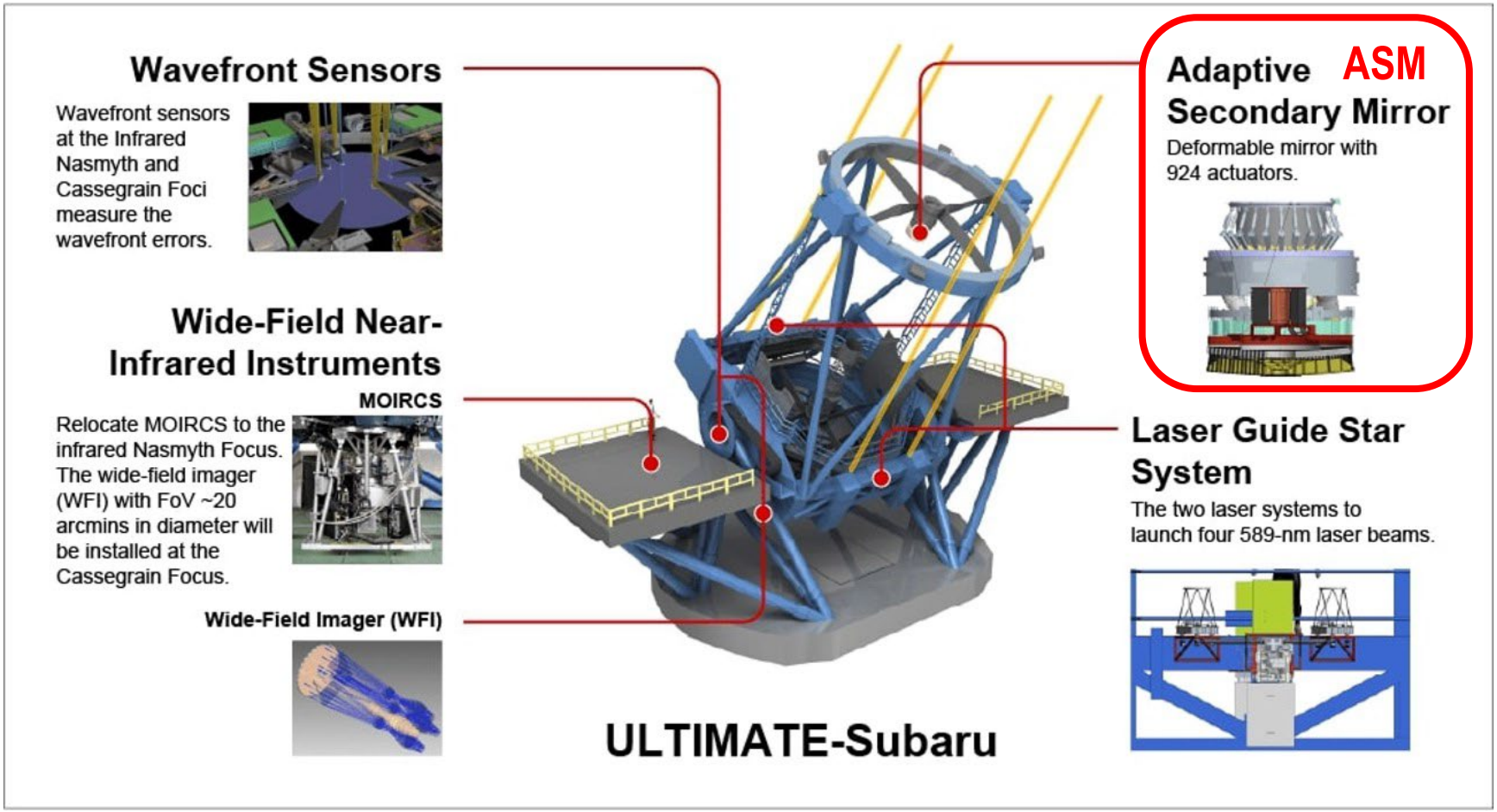
Corrects atmospheric turbulence to obtain sharp images

Main components

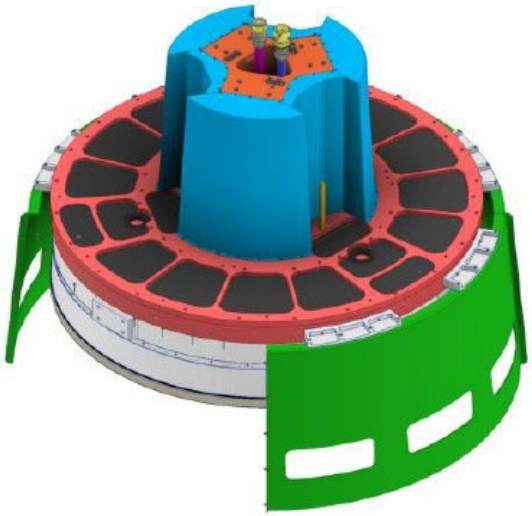
- **Deformable Mirror (DM)**
  corrects wavefront by deformation of the surface
- **WaveFront Sensor (WFS)**
  detects atmospheric turbulence (residual of the correction)
- **Real-Time Controller (RTC)**
  calculate required correction to cancel the atmospheric turbulence (residual)
- **Laser Guide Star (LGS)**
  artificial reference light source

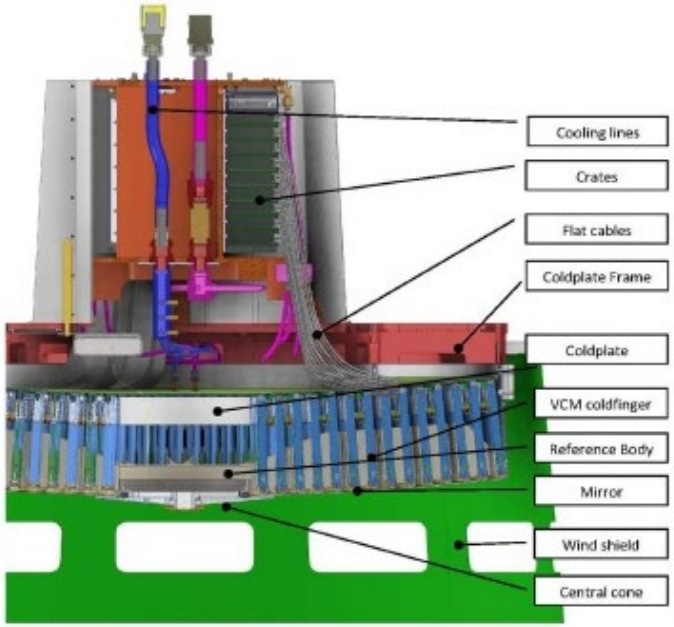
Subaru ASM

One of main components in GLAO system of ULTIMTE-Subaru project



Subaru ASM: Design





AdOptica = Microgate + A.D.S. International
http://www.adoptica.com/

General design of AdOptica systems

Deforms thin glass shell by non-contact magnetic force

Main system components:

- thin shell (t~2mm)
- reference body (Zerodur)
- cold plate (aluminum)
- actuator and capacity sensor
- control electronics

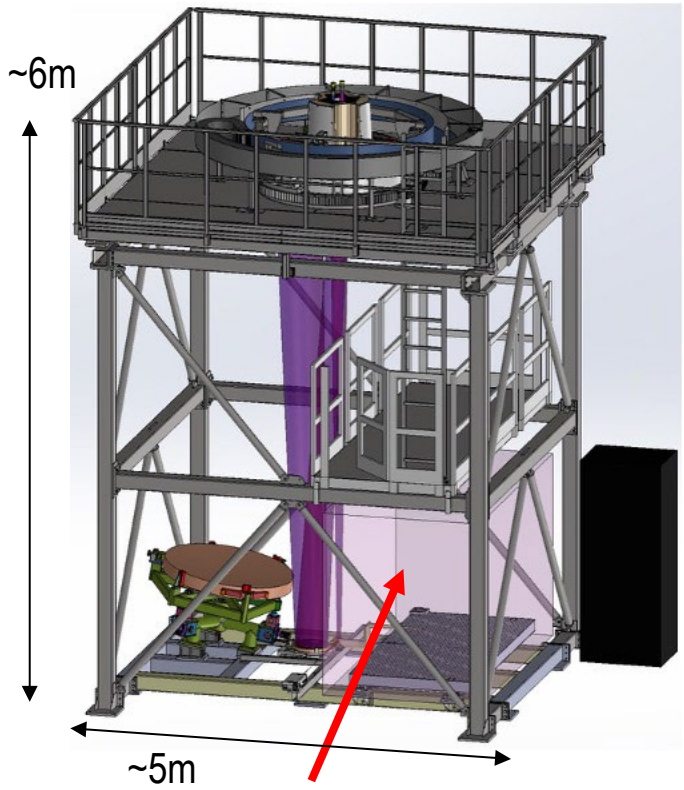
Customized with Subaru InfraRed Secondary Mirror (IRM2)

- Opto-mechanical compatibility
  including top-unit exchange w/ additional on-unit battery.
- Coolant compatibility

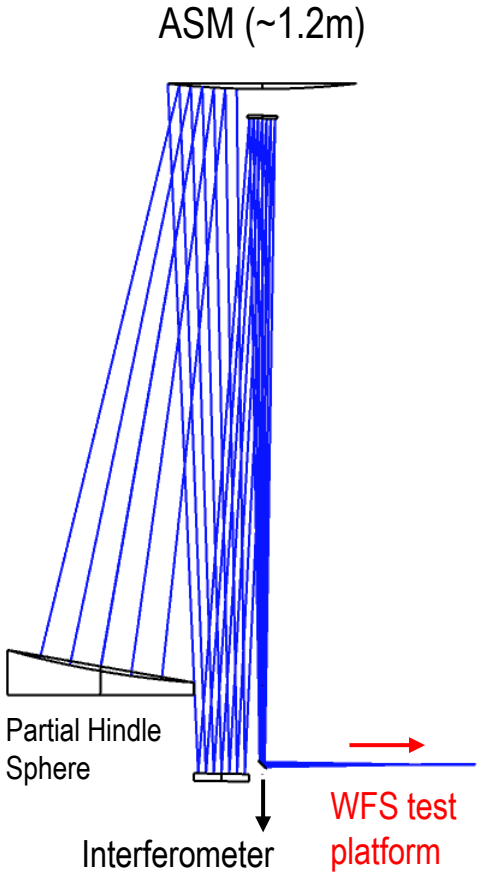
Subaru ASM: Calibration

Optical Test Tower (OTT)

- Optical verification of the ASM surface by an interferometer
- Partial closed-loop test by GLAO WFS



Stitching Hindle Test

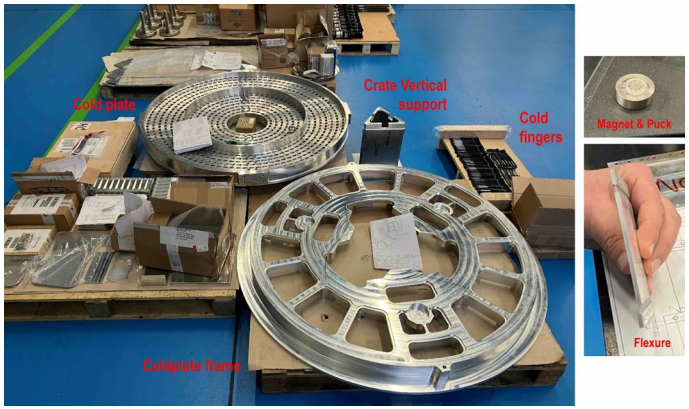


GLAO WFS will be installed here for laboratory tests before installing on the telescope.

ASM: Progress

- **Mechanical parts (ADS)**

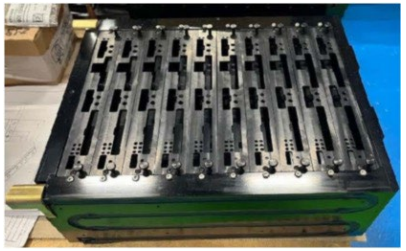
FY2023



FY2024

Cold plate w/ coolant pipes and anodized frame

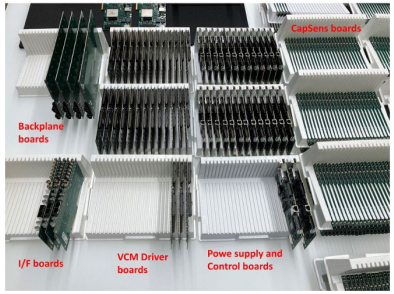
Electronics crate



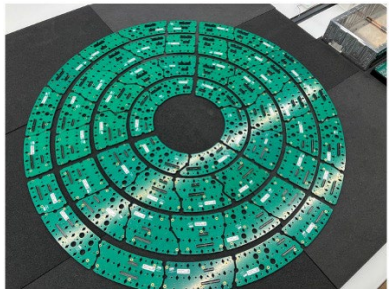
- **Electronics (Microgate)**

FY2023

Controller boards

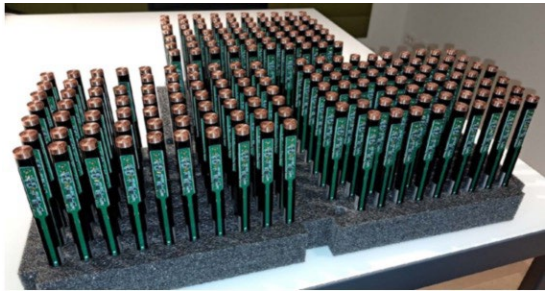


Distribution boards



FY2024

Actuators



Delivery to Hawaii will be in FY2027

Social Implementation

AO is a technique to

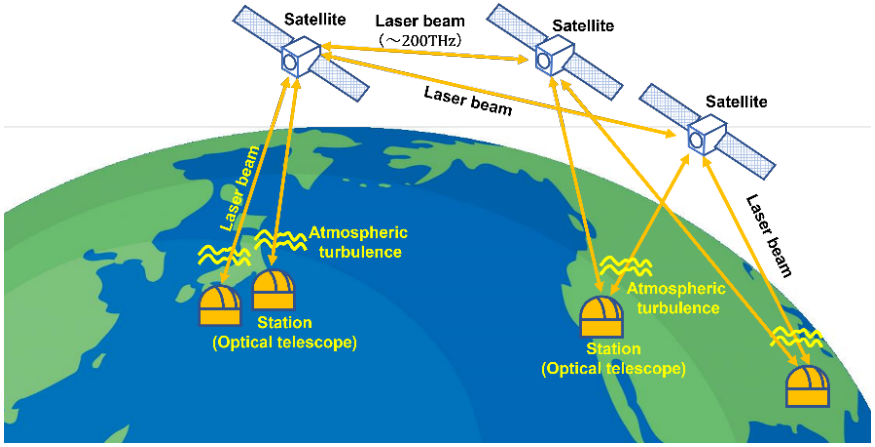
"Achieve diffraction-limit by correcting the phase disturbance of optical wavefront".

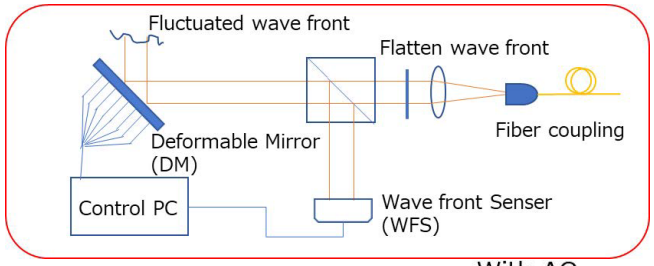
⇒ improving resolution & sensitivity

The light source is not necessarily an astronomical object (The source of disturbance is not necessarily atmospheric turbulence).

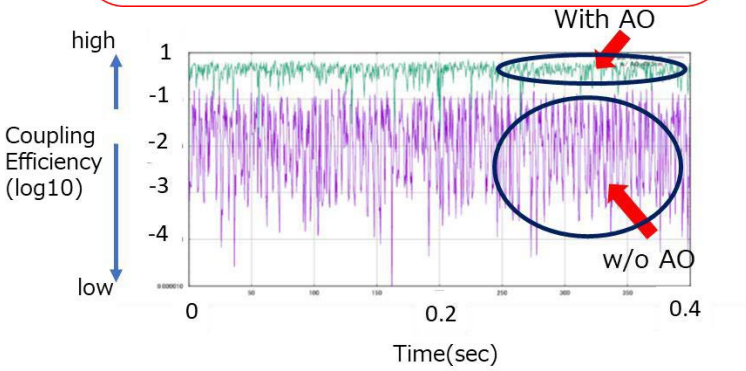
⇒ application to other research field than astronomy

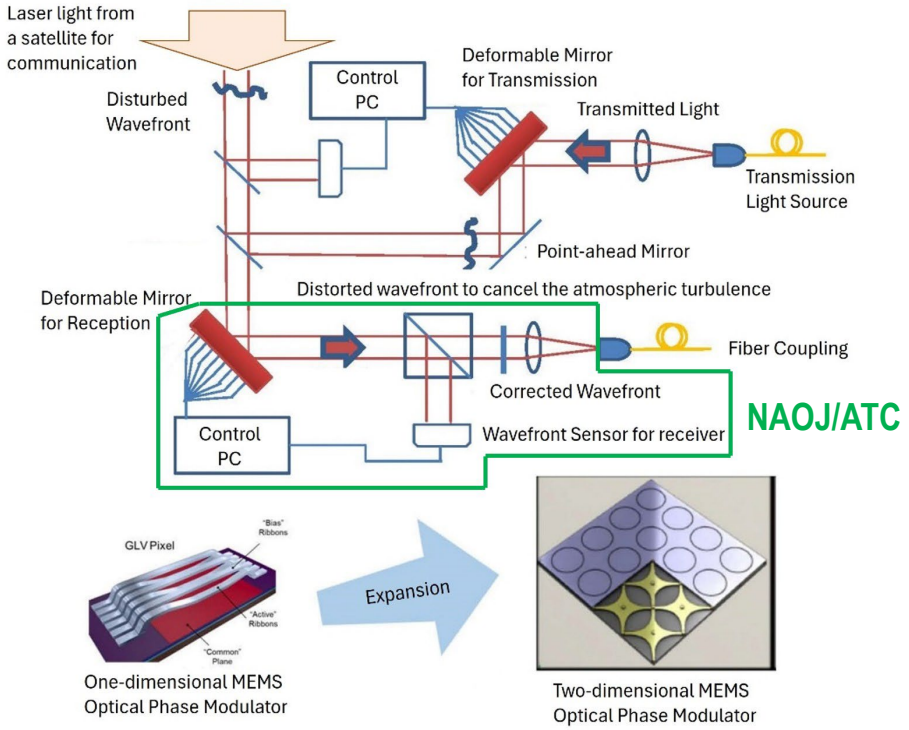
AO for Optical Satellite Communications





Saito+23, OFC23, Th1H.3





Minutes of **I**nternal affairs and **C**ommunications R&D contract: **"Research and Development of Next-Generation Adaptive Optics Device for Satellite Optical Communications"**
https://www.screen.co.jp/news/NR230831

SCREE HD Co., Ltd, NICT, **NAOJ** (~ $2M x 4yr)

Improvement of two order of magnitude on average (at least 3 times = 5dB)

MIC-AO overviews

Conditions

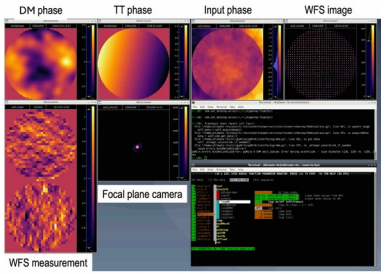
Items	Values
Environment	
Reference wavelength	1550 nm
Observing direction	Zenith (Elevation = 90 deg)
Fried length	2 cm
Telescope	
Diameter	2 m
Performance	
Evaluation wavelength	1550 nm
Numerical aperture	NA=0.1 (0.4162 arcsec on the focal plane)
Improvement of coupled light amount	> 5 dB (3 times) in each frame

Requirements

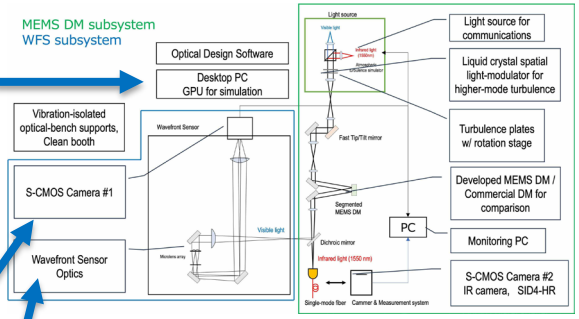
Items	Values
Phase modulator	
Element number	> 10,000
Spatial filling factor	> 70 %
Control speed	> 100 kHz
Control system	
Control loop frequency	> 10 kHz

Control Software

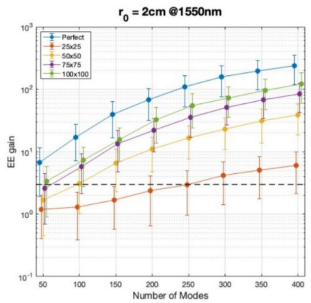
Control test using simulated data

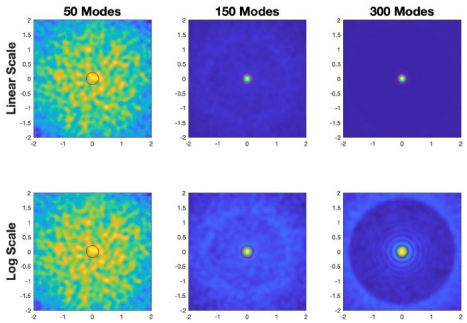


Schematic diagram of the AO system



Simulation results



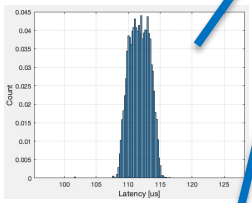


Relation between the number of correction modes and Encircled Energy(EE) at 1,550nm when r0 = 2cm.
The black dashed line indicates the goal of the system. EE is evaluated by Full-Width at Zero-Intensity (FWZI) for NA = 0.1, corresponding 0.39 arcsec for a 2-m aperture.

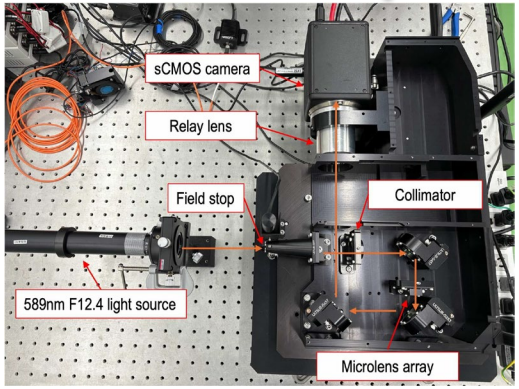
Change of point-spread-functions (PFSs) by the number of correction modes for a 2-m circular aperture at 1,550nm. The size of each panel is 4 arcsec square. Red circles at the center corresponds to FWZI for NA = 0.1.

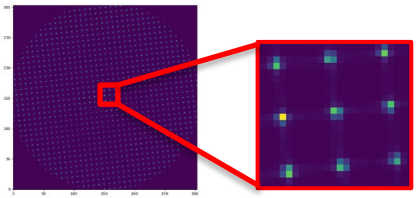
Wavefront Sensor

Measured latency of the WFS camera (~100us)



Optical alignment

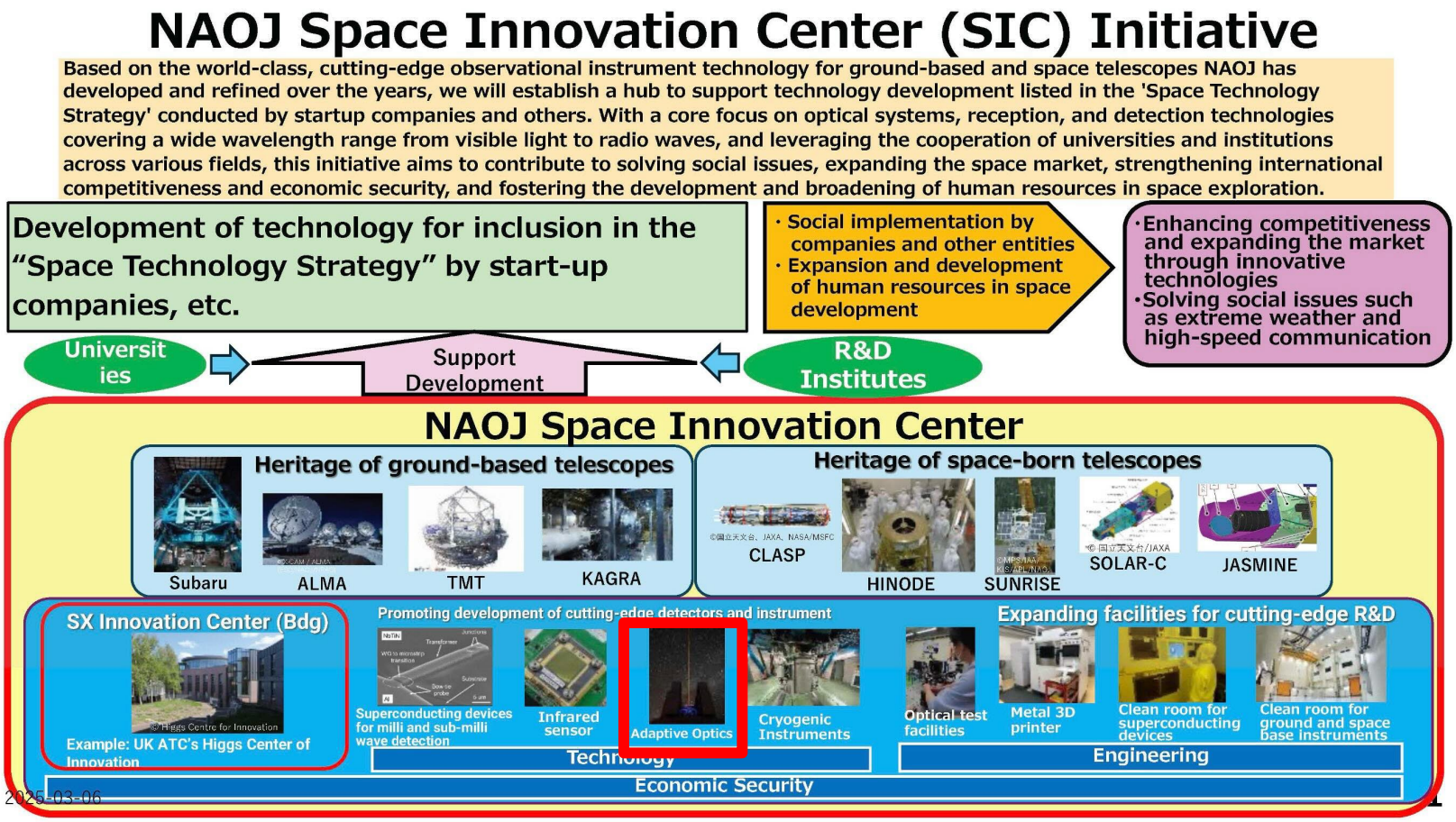




Shack-hartmann spot diagram
(32x32 lenslet array)

Space Innovation Center

Independent of ATC on the organization structure of NAOJ



Adaptive Optics is listed as a part of key technologies.

Job opportunities starting in the next FY is planned.

Summary

AO development activities at ATC

- NAOJ Project

  ULTIMATE-Subaru

  Adaptive **S**econdary **M**irror (ASM)

- Social Implementation Activity
  - Optiucal satellite communications
  - Space Innovation Center