ULTIMATE-Subaru: Current Status

Yosuke Minowa (Subaru Telescope)
on behalf of ULTIMATE-Subaru project team

ULTIMATE Subaru

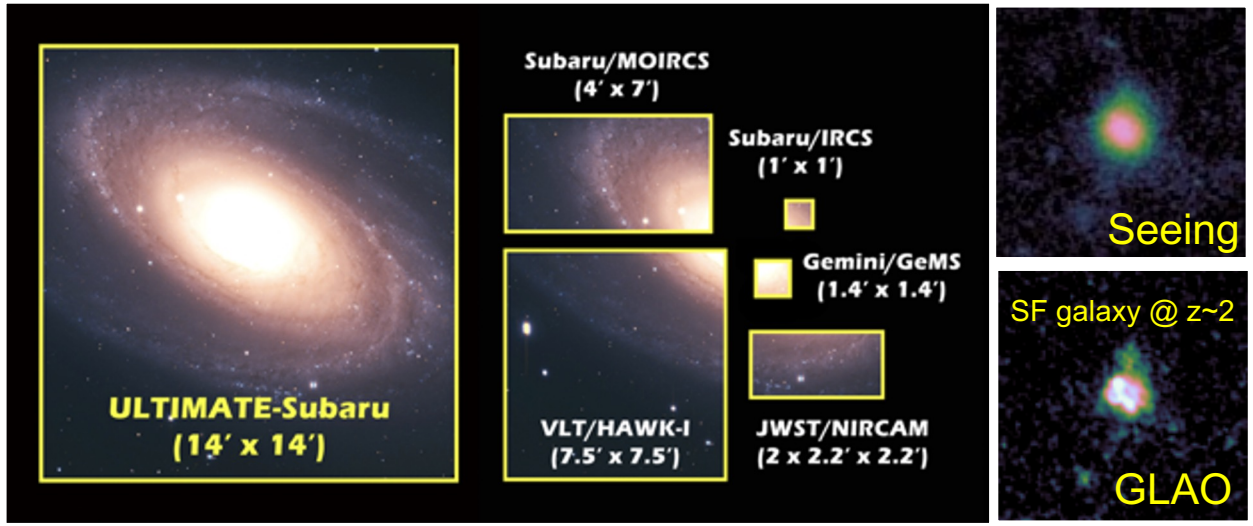
Agenda

- ULTIMATE-Subaru Science Capabilities
- ULTIMATE-Subaru Instrument Overview
  - **GLAO Preliminary Design**
  - **Prototyping Activities**
  - Science Instrument Current Status
- Project timeline
- Funding situation
- Summary

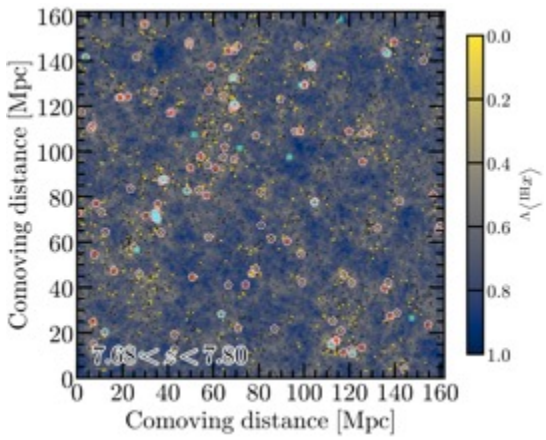
GLAO Preliminary Design Review on Nov 22,23

ULTIMATE-Subaru Science Capabilities

Ultra-wide Laser Tomographic Imager and MOS with AO for Transcendent Exploration

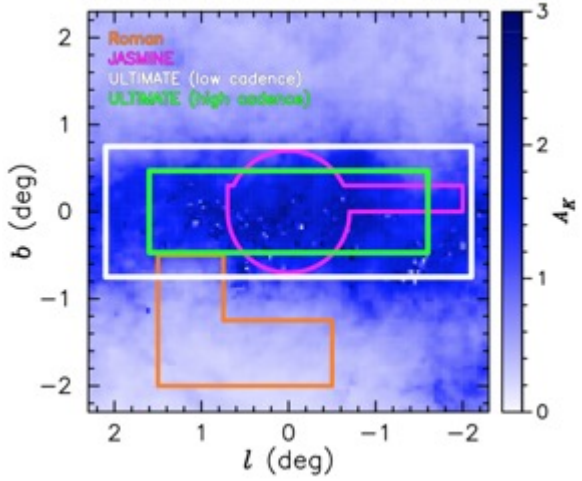


- Widest AO corrected Science FoV (14'x14' science FoV)
- Image quality comparable to HST (FWHM~0".2 at K)



Enhanced sensitivity

- Survey for first galaxies, Reveal the massive galaxy formation
- Synergy with Roman and Euclid with wide-variety of NB/MB filters.

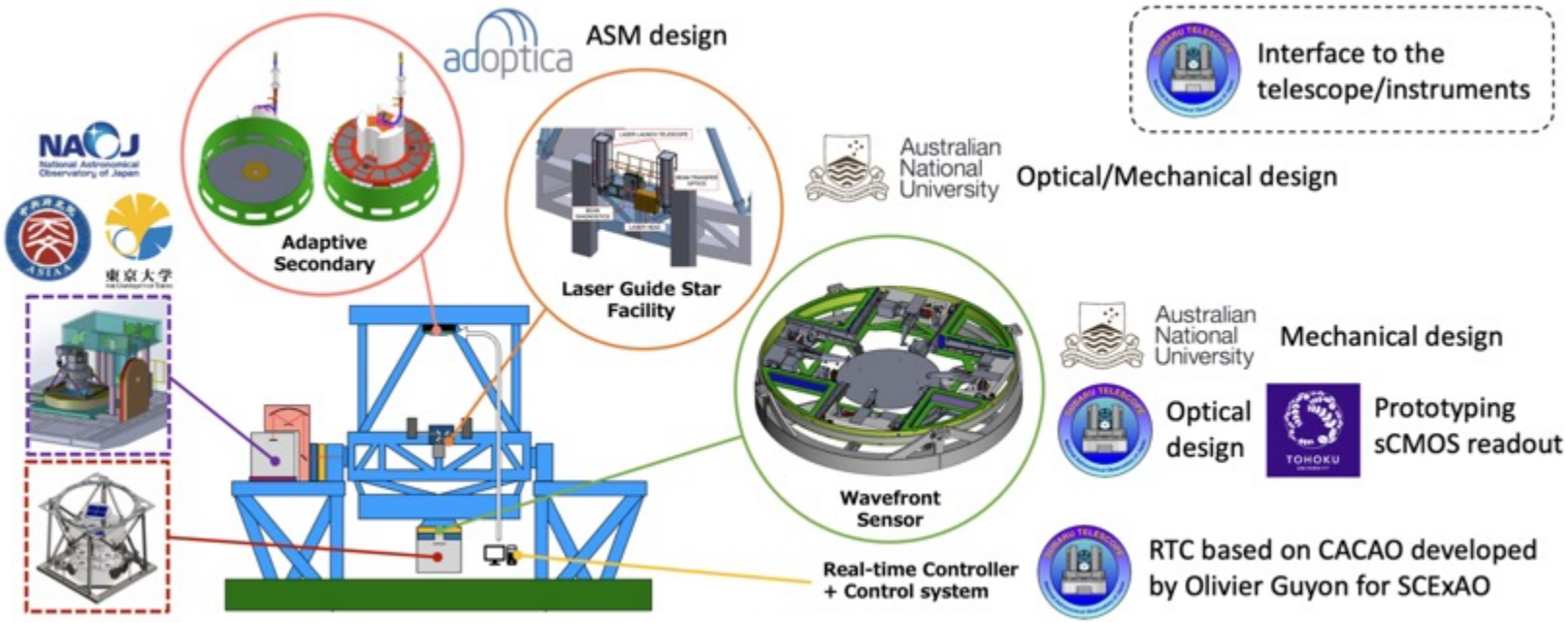


Enhanced spatial resolution

- Spatially resolved studies of high-z galaxies
- Transient/Astrometric survey at the Galactic Center region
- Synergy with Roman and JASMINE with high-cadence observations.

ULTIMATE-Subaru: Instrument Overview

GLAO assisted wide-field NIR instruments

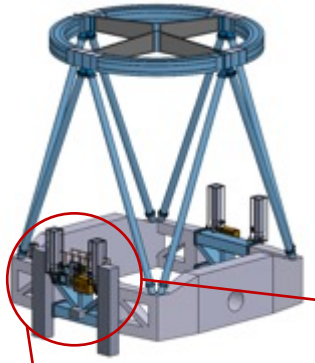


- Subaru/NAOJ-led project in collaboration with
  - Australian National University (ANU, Australia)
  - Tohoku University (Japan)
  - Academia Sinica Institute of Astronomy and Astrophysics (ASIAA, Taiwan)
  - University of Tokyo (Japan)

Progress in FY2022

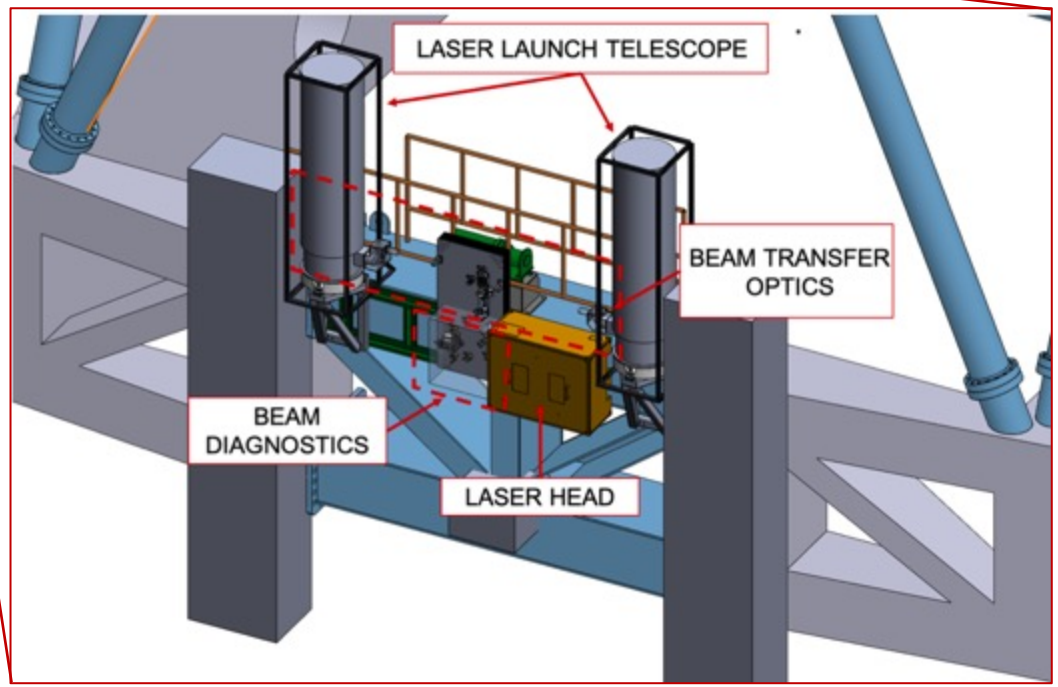
- The science instrument plan has been revised after the CoDR in FY2021
- ASM finished the final design. Procurement started for long-lead optical components.
- GLAO preliminary design study completed, PDR in Nov 2022, Starting final design phase.

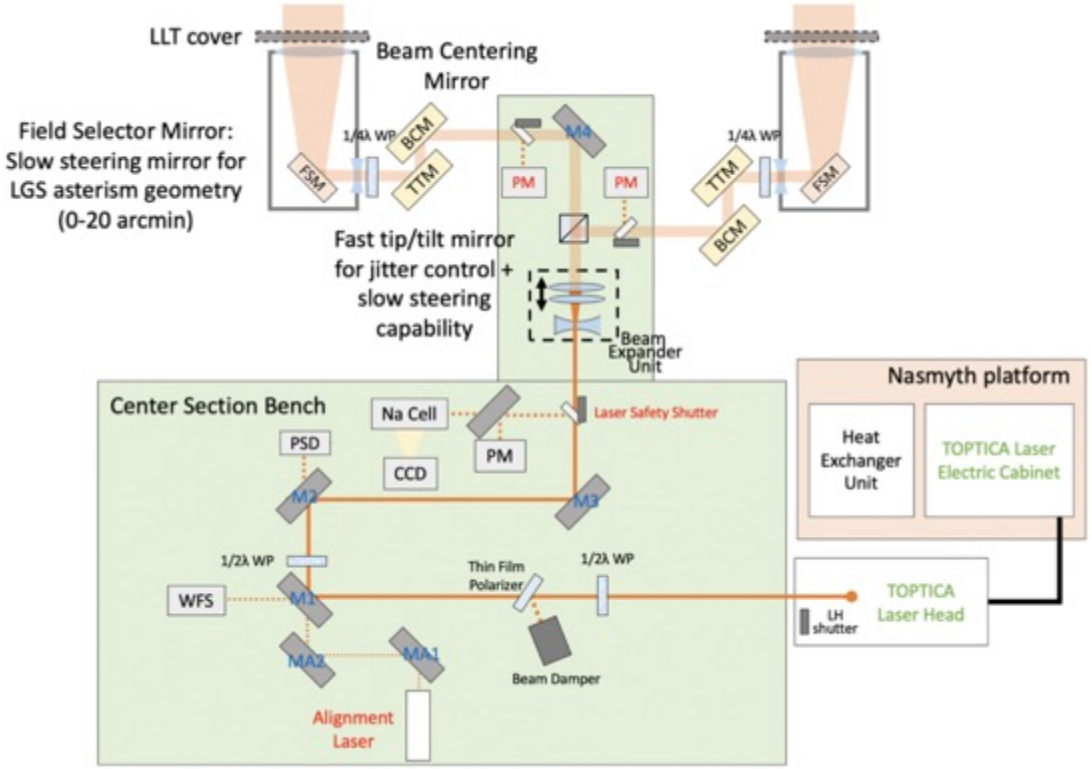
Laser Guide Star Facility



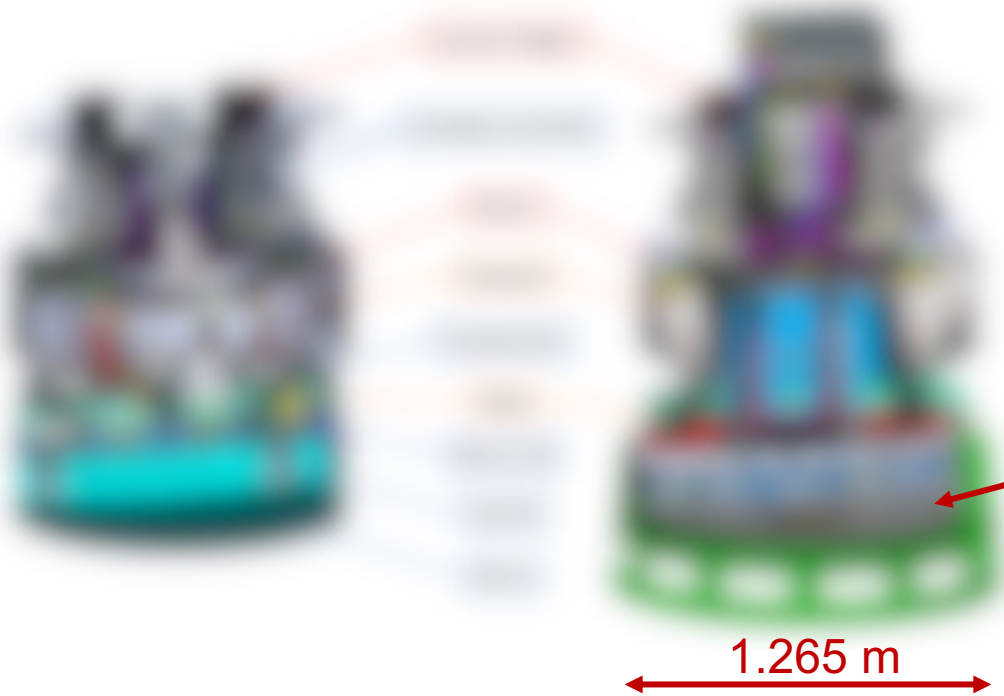
- 4 laser beams are propagated from the front/rear side of the telescope center section.
- Use two TOPTICA 20W lasers, split the laser beam into two (**~10W each**)
- LGSF is composed by the diagnostic part (power, wavelength, alignment), beam transfer part (expand, split the beam, jitter control), and launching part (LLT, field steering mirror)
- The asterism can be configured at **any diameter within 0 – 20 arcmin**.

Martinez, N. et al. 2022 Proc. SPIE





Adaptive Secondary Mirror

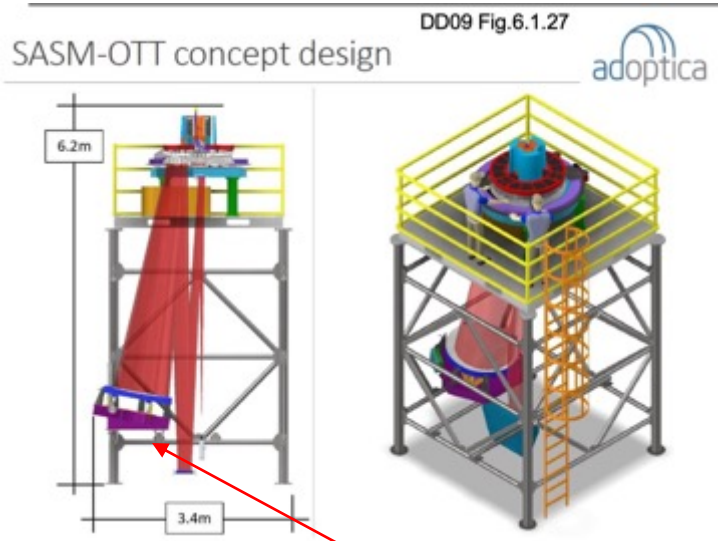


(model courtesy of MELCO and AdOptica)

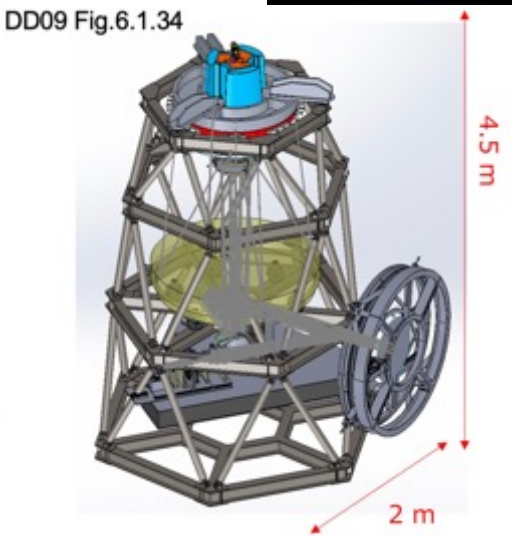
- Adopt a design from AdOptica based on the VLT DSM design.
- Install in the existing secondary hexapod (IRM2) at the Subaru.
- **Designed to withstand the frequent (every 2 weeks) exchange between the ASM and prime-focus unit (HSC, PFS).**
- Final Design completed, **Started production in FY2022**

Oya, S. et al. 2022 Proc. SPIE

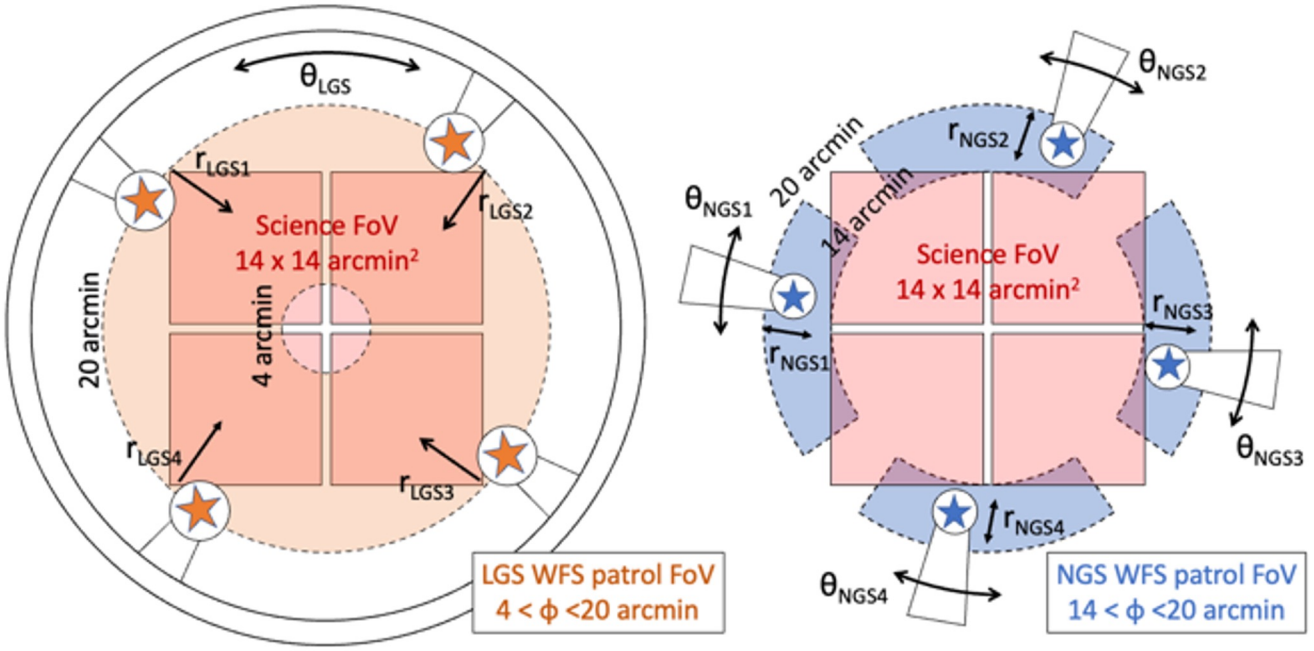
- **ASM calibration unit**
  - ASM surface shape flattening (stitching interferometry)
  - AO calibration between WFS and ASM (Full aperture)
    - Test the real-time control software in advance
    - Simulate the acquisition procedure
    - Reduce a lot of commissioning time

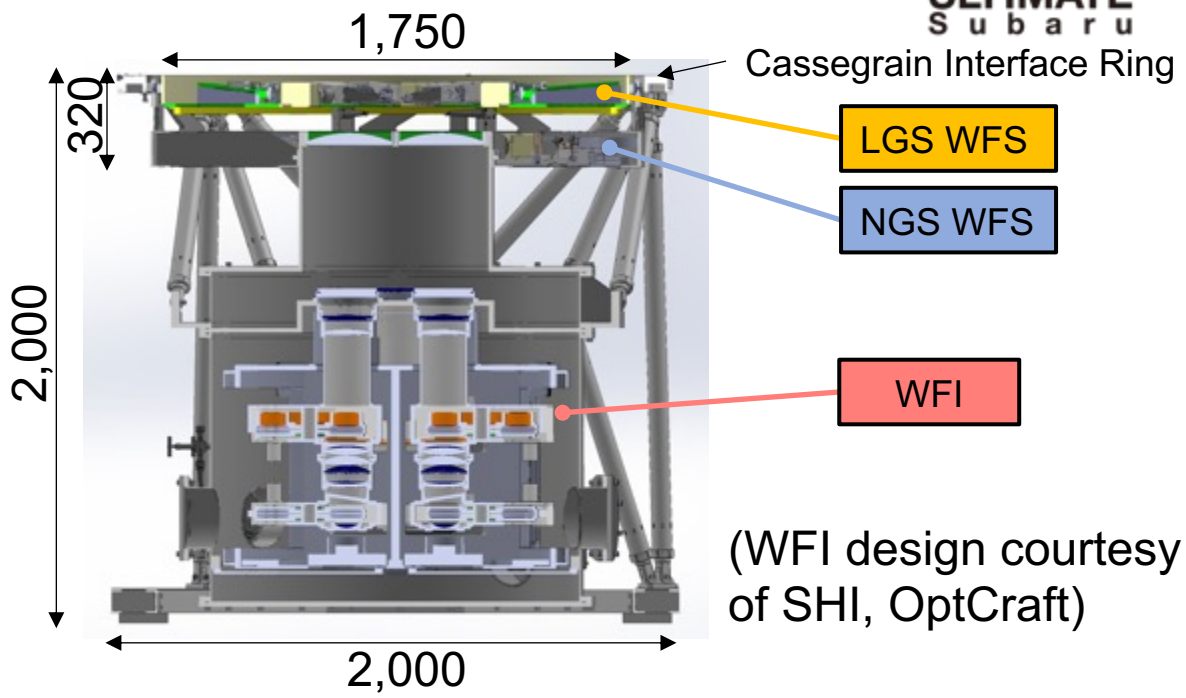


PHOTOCROSS

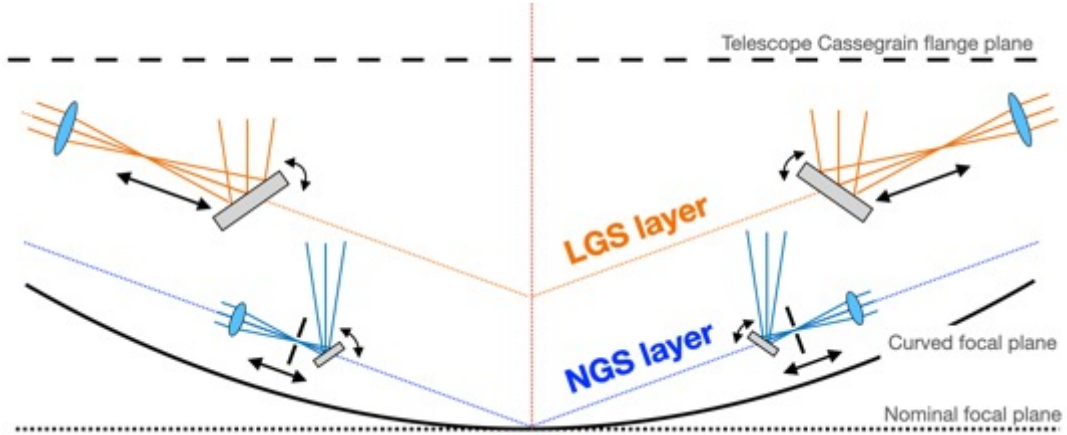


Wavefront Sensors covering 20’ field





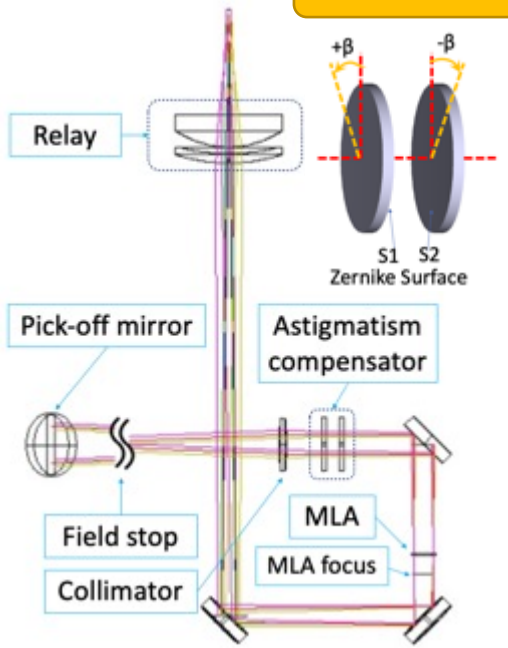
(WFI design courtesy of SHI, OptCraft)

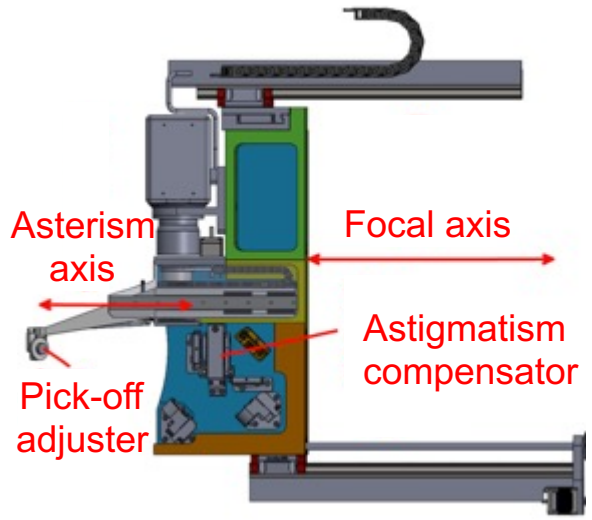


- LGS WFS patrol FoV: Radius=**2-10 arcmin** (narrow-field mode available)
- NGS WFS patrol FoV: Radius = **7-10 arcmin** (outside of science FoV)
- Each WFS moves along the slope that best fits the curved focus
- Pick-off mirror can be tilted to compensate for non-telecentricity
- All WFSs are configured in the limited envelope (1750 dia. x 320 t) on the science instrument (WFI)

Wavefront Sensors

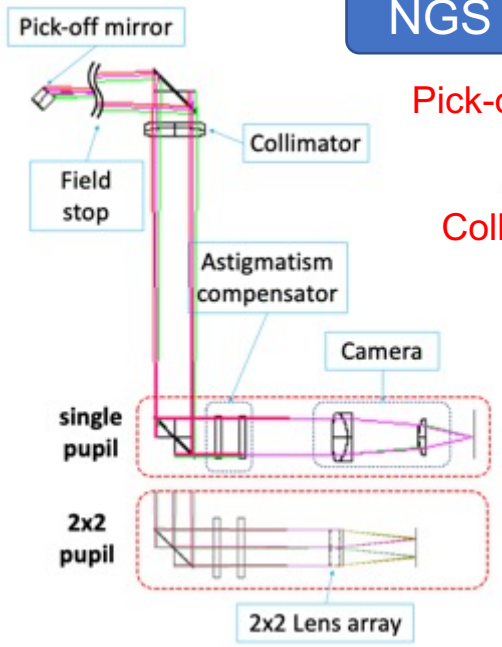
LGS WFS design

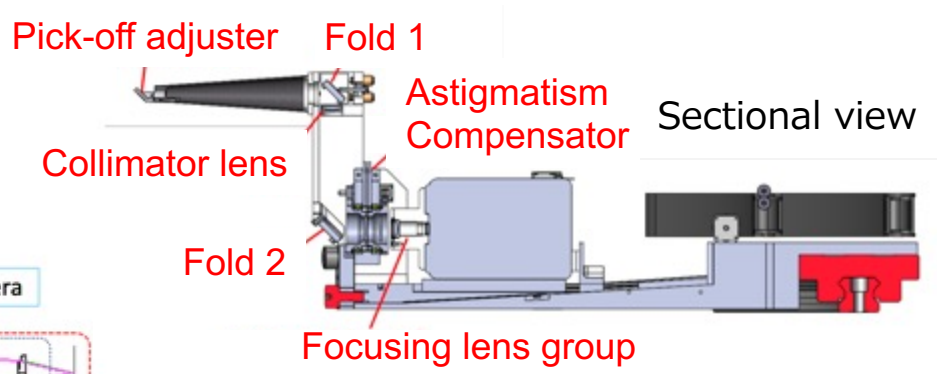




Top view

NGS WFS design





Sectional view

Tanaka, Y. et al. 2022 Proc. SPIE
Martinez, N. et al. 2022 Proc. SPIE

- LGS WFS: 32x32 SH-WFS for high-order modes
- NGS WFS: 1x1 for tip/tilt or 2x2 for tip/tilt + focus
- An astigmatism compensator to compensate for the telescope remaining aberration depending on the location in the patrol field.

Detector

- Hamamatsu Photonics
  Orca Fusion BT (Back-illuminated sCMOS)
- 6.5μm/pix, QE~95% @589 nm

GLAO prototype activities

- **ULTIMATE-START (Akiyama-san's talk on Day 3)**
  - LTAO mode to be implemented in the existing Subaru facility AO system
  - Develop the fundamental technologies for the future GLAO system
    - Development for the real-time controller with 4 SH-WFSs
    - Development of the laser guide star facility with the TOPTICA 20W laser

    Terao, K. et al. 2022, Proc. SPIE
- **SH-WFS with an sCMOS rolling shutter**
  - Tested the aliasing effect of the rolling shutter mode.
    - No critical performance degradation is expected for the GLAO with the rolling-shutter mode.
  - LGSF jitter measurements.

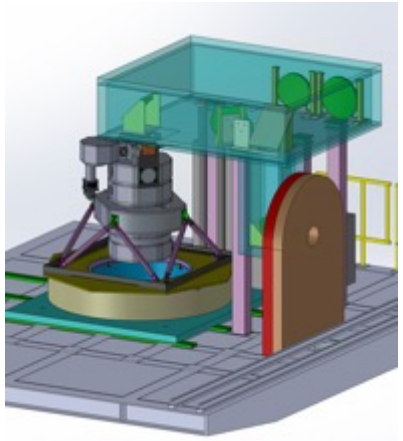
    Ogane, H. et al. 2022, Proc. SPIE
- **Turbulence Profiler for the Ground Layer Turbulence measurement at Subaru**
  - SLODAR installed at the Subaru Nasmyth focus.
  - GL-turbulence including the dome seeing can be measured.
  - Initial data obtained in Nov, 2022.

Wide-Field NIR instruments with GLAO

Successfully passed a conceptual design review on June 2021

FIRST LIGHT INSTRUMENT

Reuse. MOIRCS at Nasmyth-IR focus with a cooled relay optics



- FoV ~ 4' x 7' (0".12/pix)
- Wavelength: 0.9 - 2.5 um
- Imager/MOS spec (R500-3000)

Suspended until Subaru's Nasmyth-IR future is clearly defined.

FIRST LIGHT WITH A PART OF WFI AT CS

- Start from a part of the instrument (e.g. half of the detectors)
- Implement full capabilities later.

PDR phase, fundraising

FACILITY INSTRUMENT FOR LARGE IMAGING SURVEY

Near-Infrared Wide-Field Imager (WFI) at Cassegrain focus

- FoV ~ 14' x 14' (~0".1/pix)
- Wavelength: 0.9-2.5 um
- Wide variety of narrow/medium band filters (designed to allow flexible filter exchange)

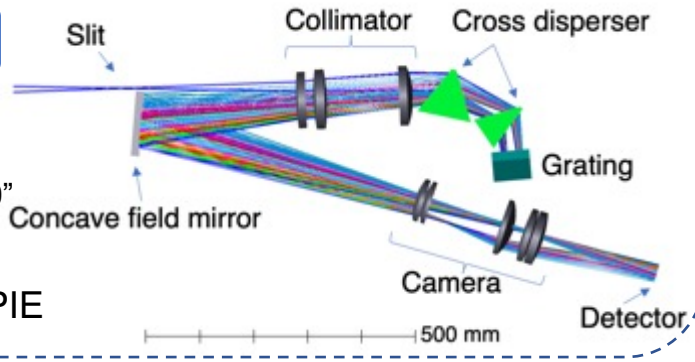
Next presentation by Motohara-san

Narrow-Field spectrograph utilizing the GLAO sub-systems (ASM,LGSF)

LTAO MODE SPECTROGRAPH (NINJA)

- Wide Spectral coverage: 0.35-2.5 um
- Narro-Field coverage : FoV < 10"
- Spectral resolution: ~ 3,000

Tokoku et al. 2022, Proc. SPIE



Subaru UM discussion in Day 3
ULTIMATE時代の近赤外線分光、面分光への期待

DAY 3 | 2 February 2023 (Thu)

09:30 - 10:40 Discussion session 2 (in Japanese)

09:30 - 09:45 (15 min) 使用済み検出器譲渡事業の報告 *(Yanagisawa)*

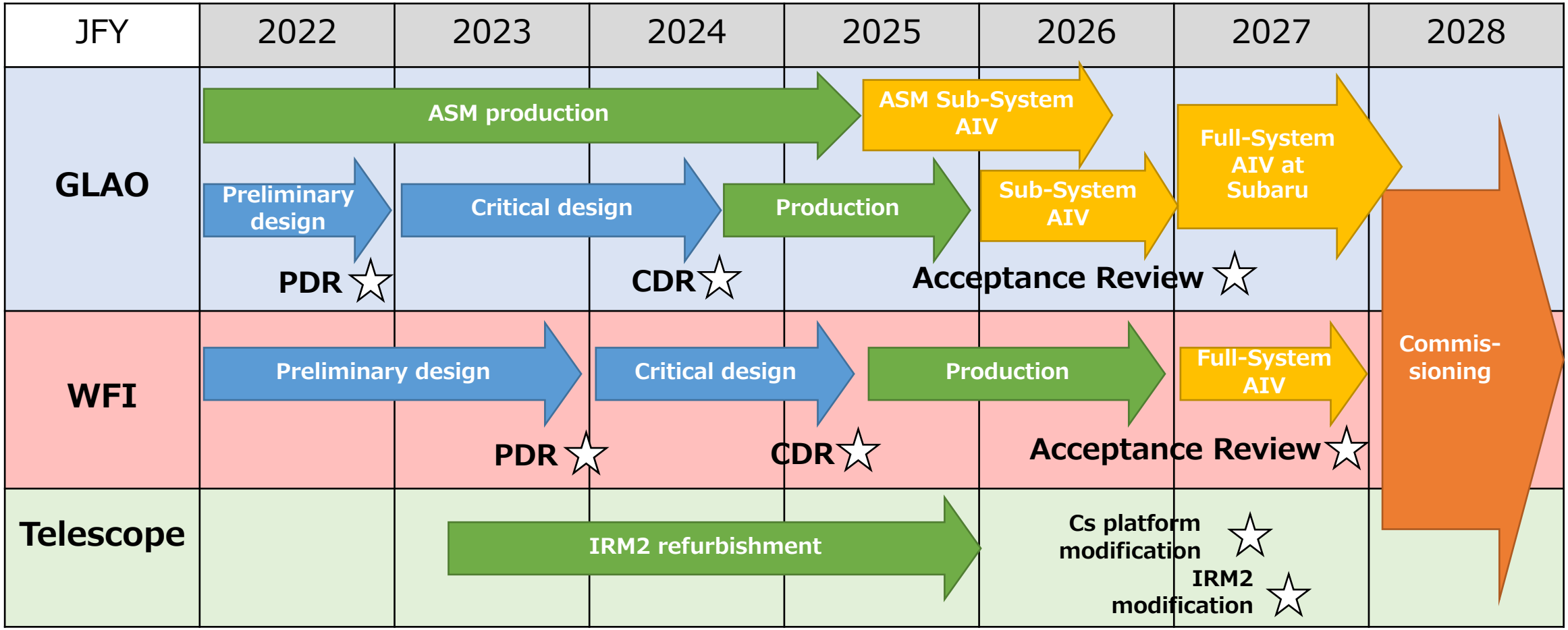
09:45 - 10:00 (15 min) SuprimeCam 2号機（FDCCD)の有効活用の議論 *(Yanagisawa)*

10:00 - 10:40 (40 min) ULTIMATE時代の近赤外線分光、面分光への期待 *(Koyama)*

- No future plan for wide-field NIR spectrograph.

- What are scientific demands in 2030s (after GLAO)?
  - Restart MOIRCS project?
  - Other GLAO-assisted instruments? (multi-IFU, wide-field IFU, etc.)
  - Completely new idea (Subaru 3)?

ULTIMATE-Subaru Project Timeline



ULTIMATE funding situation

- **GLAO project is funded through MEXT (「すばる望遠鏡の高度化」)**
  - Production of the Adaptive Secondary Mirror has been started.
  - Finalizing the design of the other subsystems
  - Additional fundraising is necessary to cope with increasing procurement and labor cost.

- **Science instrument has not been funded yet**
  - Applying for the large JSPS grant to kick-off the WFI development.
    - International partnership is essential to fully develop WFI.
  - NINJA (narrow-field, wide-band spectrograph) project is funded
    - JSPS grant (Kiban-S, PI: M. Yoshida)
  - No activities for the other potential science instruments.

Summary

- ULTIMATE-Subaru is a wide-field NIR survey instrument with GLAO, which is one of the main facility instruments for Subaru2 focusing on wide-field survey.
- The GLAO consists of the Adaptive Secondary Mirror (ASM), the Wavefront Sensors (WFS), the Laser Guide Star Facility (LGSF), and the control system providing the **enhanced seeing (a factor of 2 improvements) up to 20 arcmin FoV**.
- The preliminary design of the GLAO sub-systems have been successfully completed by the team composed by Subaru, ANU, Tohoku Univ. with close collaborations with the science instrument team composed by ASIAA, Univ. of Tokyo, and NAOJ.
- Prototyping activities to validate the feasibility of the selected design have been conducted in parallel, demonstrating the initial results. More to come in FY2023.
- GLAO has been funded by MEXT (special purpose budget) and is expected to complete the final design in FY2024, the production phase in FY2026, installation in FY2027, and the first light in FY2028.
- Concentrate on WFI as a first light science instrument for ULTIMATE.