Overview of AO activities at Subaru telescope

Yoshito Ono (Subaru)
Yosuke Minowa, Christophe Clergeon, Olivier Guyon, Julien Lozi,
Sebastien Vievard, Vincent Deo, Kyohoon Ahn, Takashi Hattori (Subaru),
Akiyama Masayuki, Koki Terao, Hajime Ogane (Tohoku Univ.)

AO upgrades in the next 2-3 years

1. Provide improved performance and new AO capabilities

2. Improve efficiency and flexibility of AO operation

3. Technical demonstration for ULTIMATE-Subaru and TMT-PSI

Related posters for details of each projects

[p02] ULTIMATE-START : project status	*Akiyama Masayuki*
[p07] Prototyping TMT exoplanet imaging instrumentation at Subaru Telescope	*Olivier Guyon*
[p15] SCExAO: status of the instrument, testbed and system-level demonstrator for PSI	*Julien Lozi*
[p18] Scalable, spectrally dispersed and multi-baseline nulling interferometry with photonic-based technology: the GLINT instrument	*Marc-Antoine Martinod*
[p19] Subaru Laser Guide Star Upgrade: Current Status and Schedule toward the Open Use	*Yosuke Minowa*
[p31] FIRST, a Pupil-Remapping Fiber interferometer at the Subaru Telescope : Results and Future plans	*Sebastien Vievard*

AO upgrades in the next 2-3 years

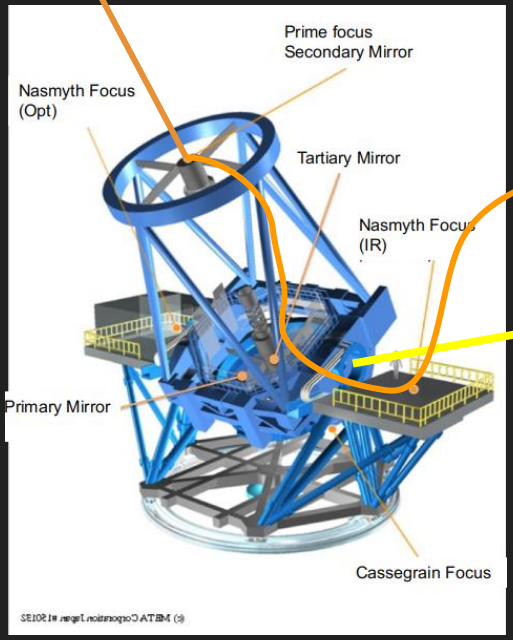
Phase 1 : Upgrade AO188 (to AO3K)

- New laser guide star system
- DM upgrade
- Near-Infrared Wavefront Sensor

Phase 2 : Advanced AO platform

- Nasmyth IR beam switching system
- ULTIMATE-START LTAO system (LTAO WFS, 4 LGS system)
- Upgrade visible WFS

Current Configuration at NsIR



Laser system
single beam
0.4W on sky
(Decommissioned)

Instrument exchange
with craning
(from SCExAO to IRCS)
Movie made by S. Vievard

188-elements
DM

188-elements
Visible WFS

AO188

IRCS

See poster [p15], [p18], [p31]

SCExAO

SCExAO
Science
Modules

IRD
@Coude

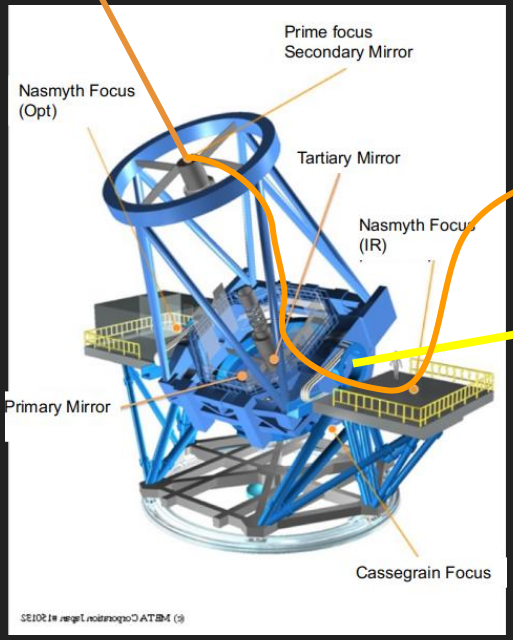
MMF

SMF (REACH)

Laser
WFS
AO system
Dichroic Mirror
DM
Sci inst.
Other
Control

Phase 1

Phase 1 upgrade



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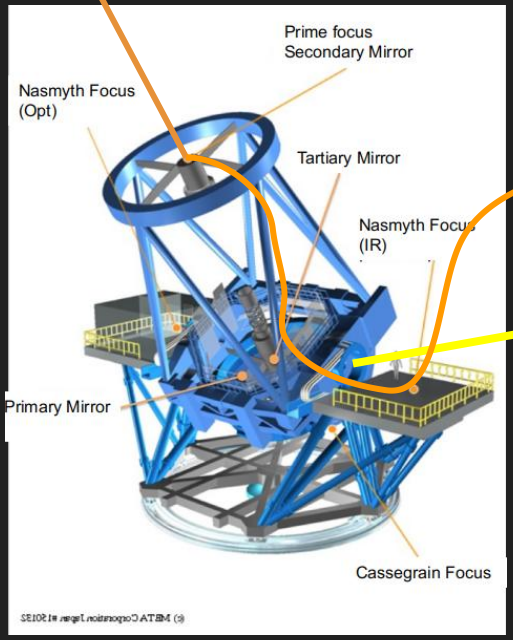
Phase 1 upgrade

- Install a new bright laser system



Laser system single beam (20W on sky)

188-elements DM

188-elements Visible WFS

AO188

IRCS

SCExAO

SCExAO Science Modules

MMF

IRD @Coude

SMF (REACH)

Laser | WFS | AO system | Dichroic Mirror

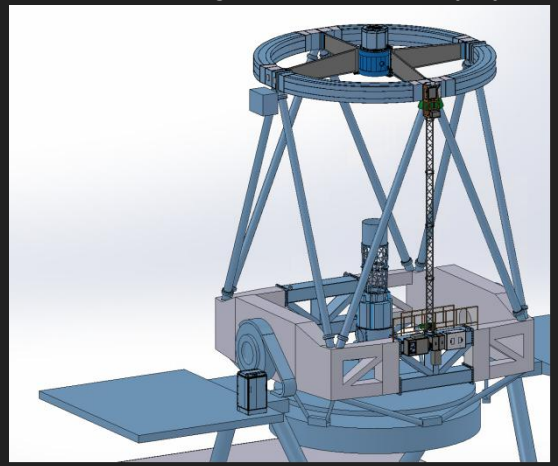
DM | Sci inst. | Other | Control

Phase 1 : New laser system

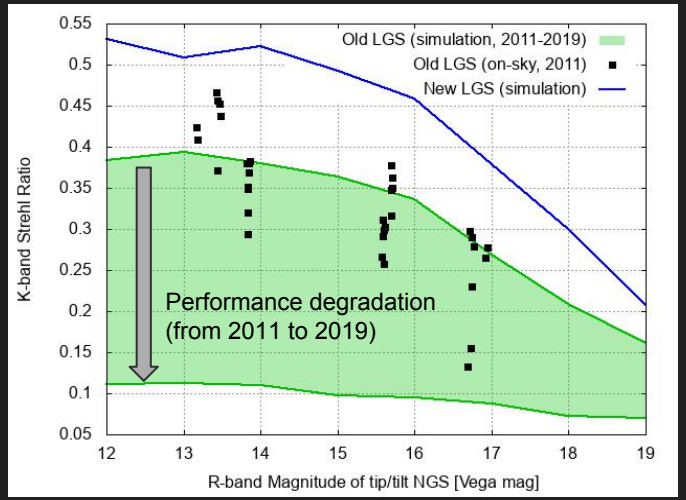
See poster [p19]

- Much better AO performance, thank to 22W powerful laser
- Better stability and easier operation and maintenance
- Installation : February, March, and April 2021
  - New mirror-based relay system will be installed to the telescope
  - 2 x 3 days downtime (February and March)
- Commissioning : April and May 2021
- Open-use : 22A

Mechanical design of the laser relay system



LGS performance (Simulation & on sky)



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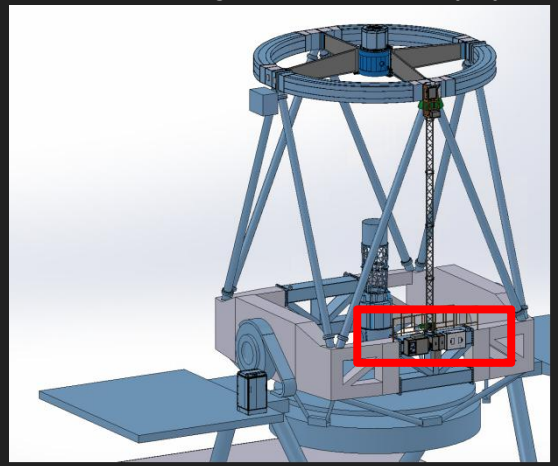
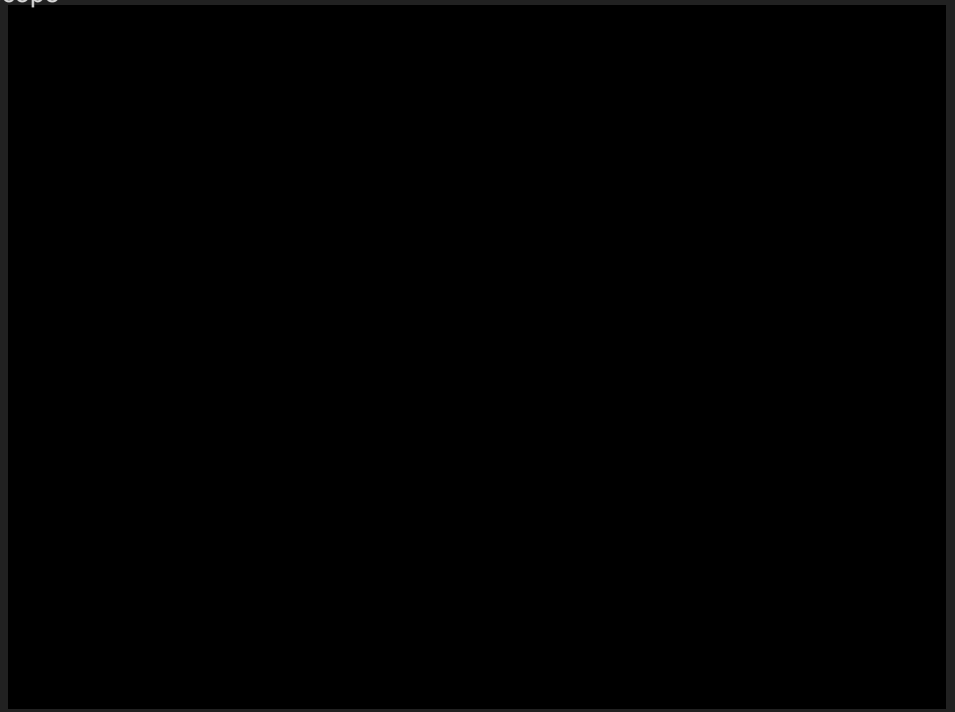
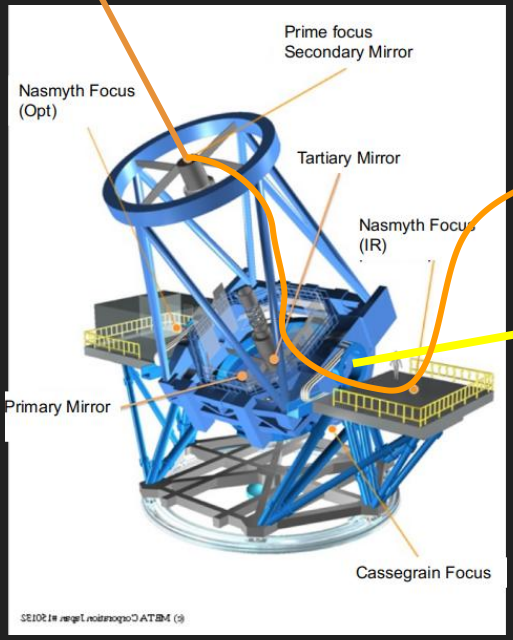


Timelapse for laser installation work on Feb.25-Feb.27



Phase 1 upgrade

- Install a new bright laser system



Laser system single beam (20W on sky)

188-elements DM

188-elements Visible WFS

AO188

IRCS

SCExAO

SCExAO Science Modules

MMF

IRD @Coude

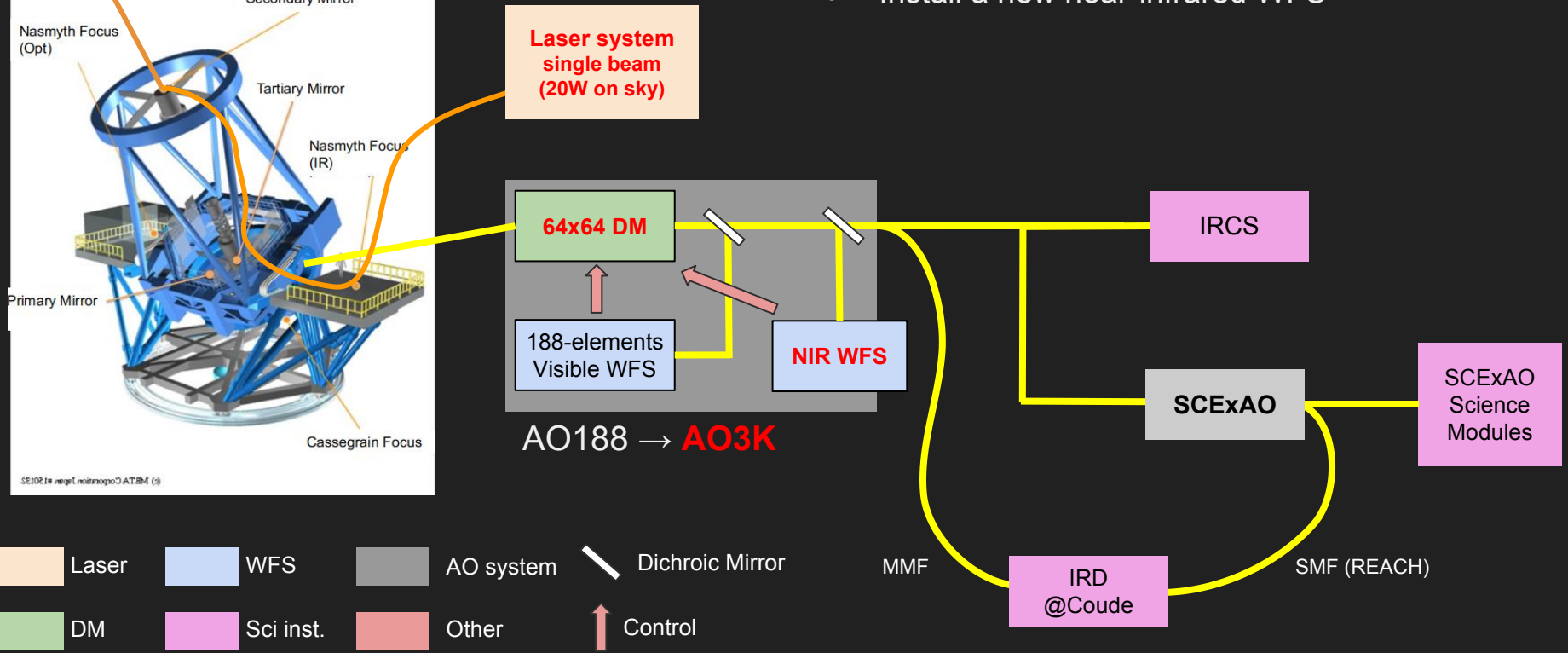
SMF (REACH)

Laser | WFS | AO system | Dichroic Mirror

DM | Sci inst. | Other | Control

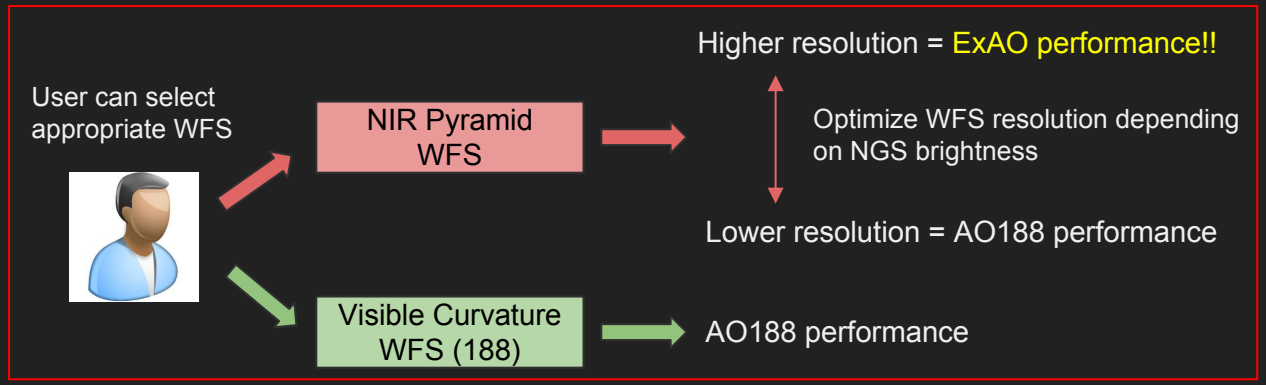
Phase 1 upgrade

- Install a new bright laser system
- Replace the AO188 DM by a 64x64 DM
- Install a new near-infrared WFS



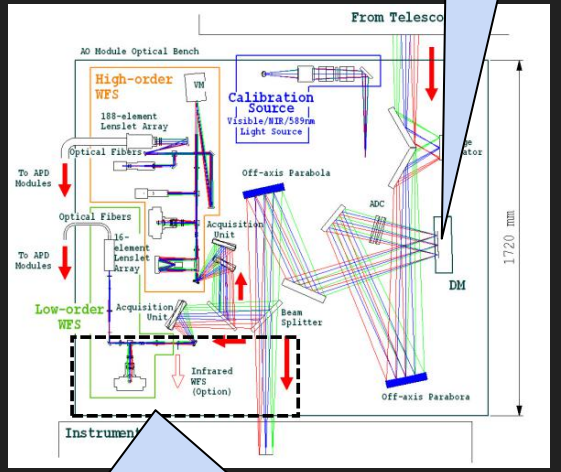
Phase 1 : 64x64 DM and NIR WFS

- Replace AO188 DM to ALPAO 64x64 DM (AO3K)
  - DM resolution is dramatically improved from 188 to 3228
  - We will receive the DM at Hilo this summer
  - Installation : 21B-21A
- Near-infrared Pyramid WFS in AO188
  - Wavefront sensing in J, H or J+H.
  - Better sky-coverage where NGS is bright in NIR (e.g GC)
  - Extreme performance in combination with DM64x64
  - WFS resolution will be adjustable by software
  - Installation : this summer Commissioning : S21B-S22A
    Open-use : S22B

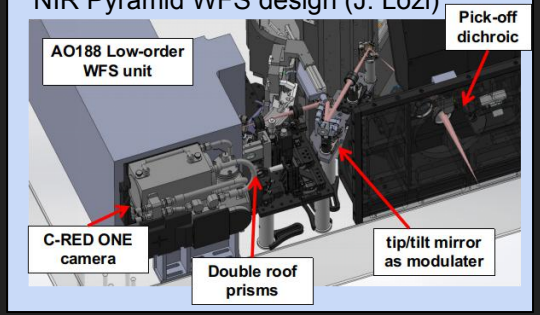


64x64 DM
(ALPAO DM3228)

AO188 optical design

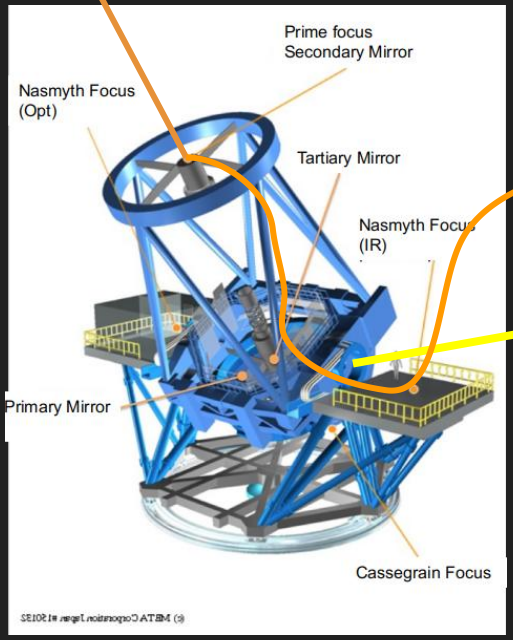


NIR Pyramid WFS design (J. Lozi)



Phase 2

Phase 2 upgrade



Laser system
single beam
(20W on sky)

64x64 DM

188-elements
Visible WFS

NIR WFS

AO3K

IRCS

SCExAO

SCExAO
Science
Modules

MMF

IRD
@Coude

SMF (REACH)

Laser
WFS
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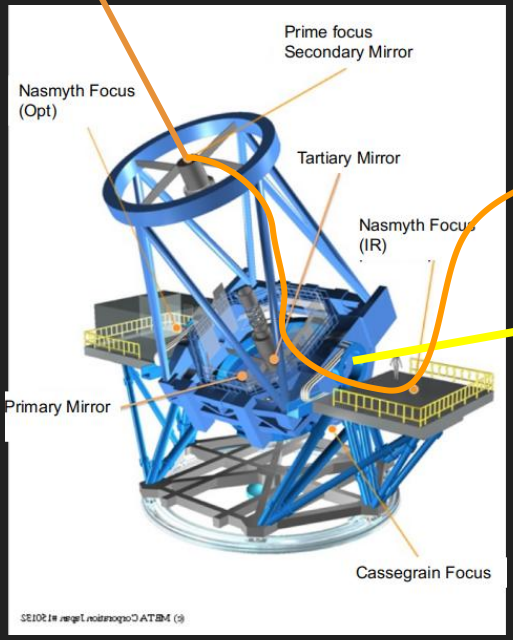
Dichroic Mirror
DM
Sci inst.
Other
Control

Phase 2 upgrade

- Install a Nasmyth beam switcher



Laser system single beam (20W on sky)

64x64 DM

188-elements Visible WFS

NIR WFS

AO3K

Nasmyth beam switcher

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SCExAO

SCExAO Science Modules

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SMF (REACH)

Laser

WFS

AO system

Dichroic Mirror

DM

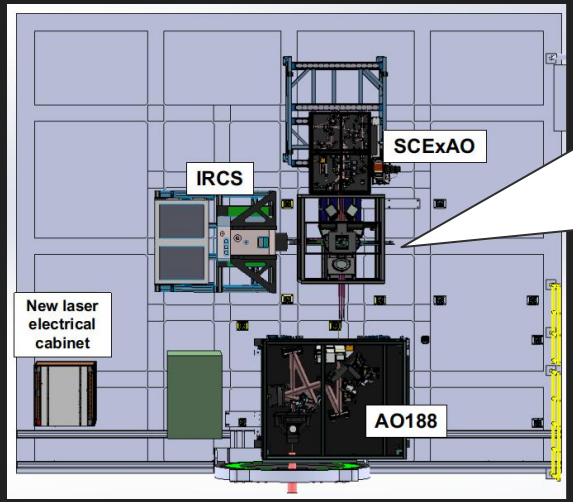
Sci inst.

Other

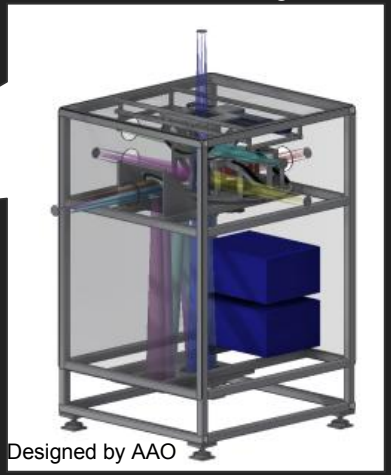
Control

Phase 2 : Nasmyth beam switcher (NBS)

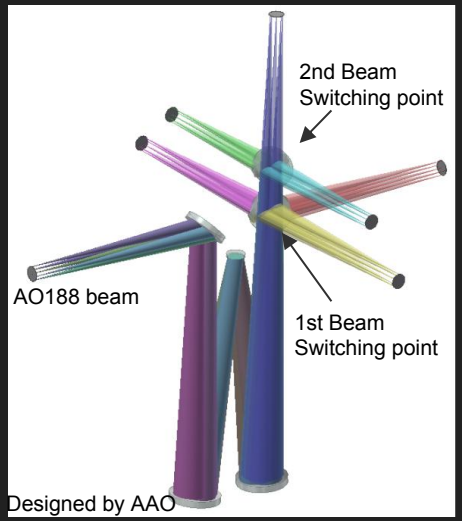
- Optical relay to redirect the beam from AO188 to downstream instruments.
  - Easy instrument exchange. No more craning work.
  - Flexible instrument exchange for queue-mode observation (best seeing: SCExAO, moderate seeing: IRCS)
  - New observation mode with a dichroic mirror (e.g. IRCS + SCExAO simultaneous observation)
- Final design will be completed soon. Fabrication and assembly cost is being requested.
- Its installation to the NsIR platform will be sometime in 2022. We may need to request some NsIR downtime for the installation and commissioning.



Entire NBS design

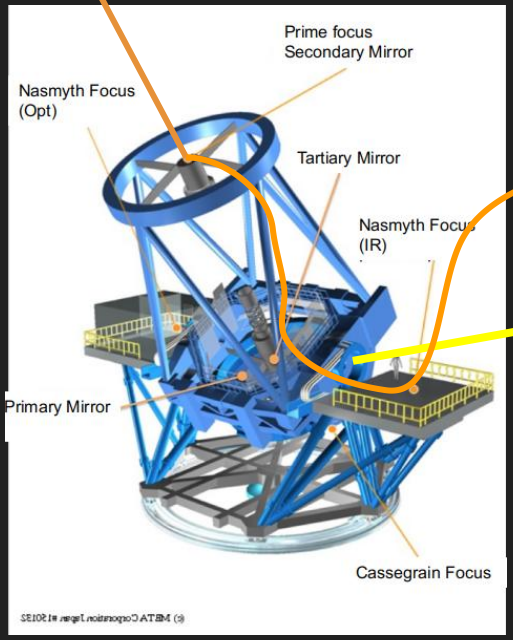


Optical path



Phase 2 upgrade

- Install a Nasmyth beam switcher



Laser system single beam (20W on sky)

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SMF (REACH)

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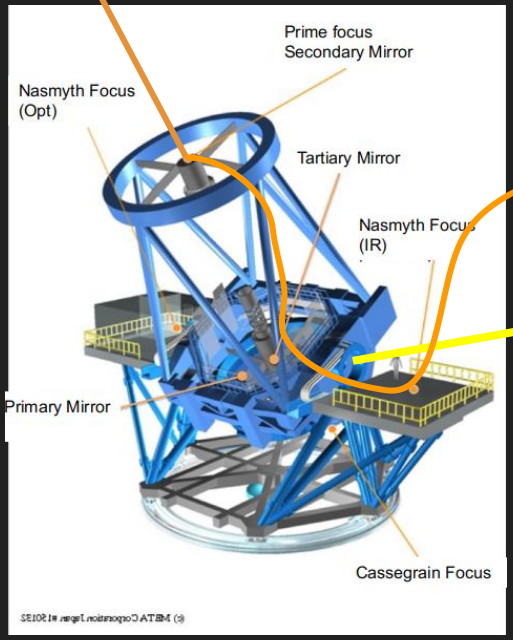
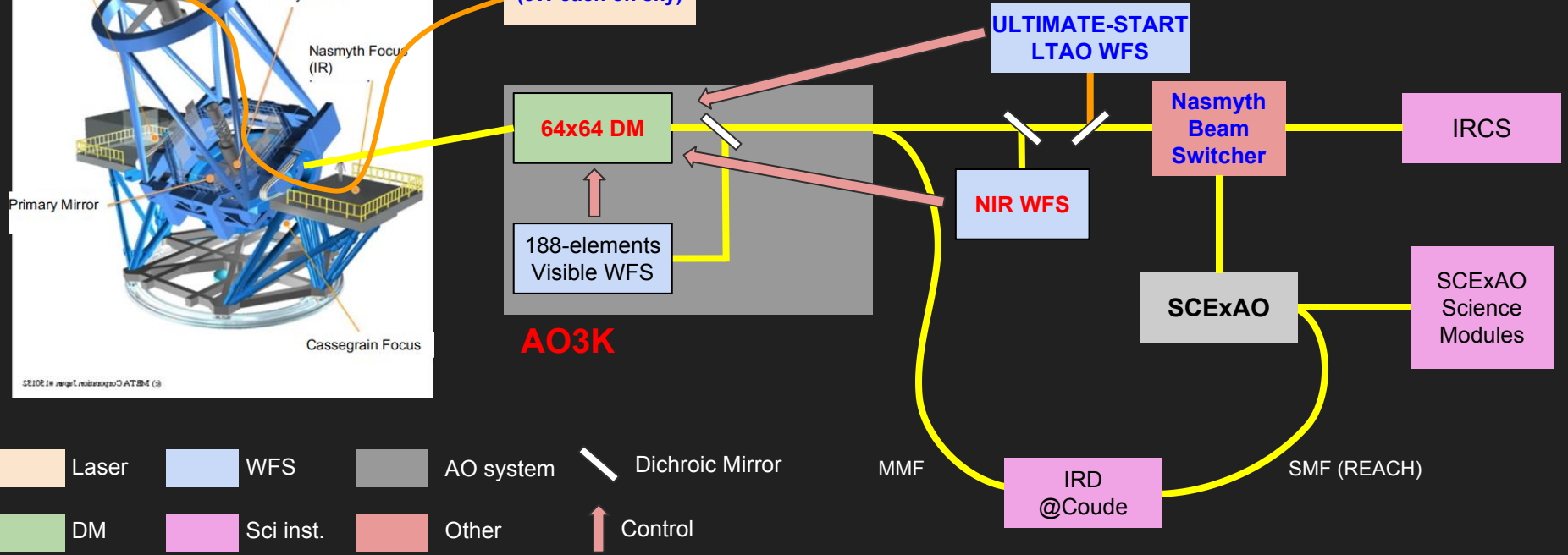
Other

Control

Phase 2 upgrade

- Install a Nasmyth beam switcher
- ULTIMATE-START LTAO system
  (LTAO WFS unit and four beam laser system)

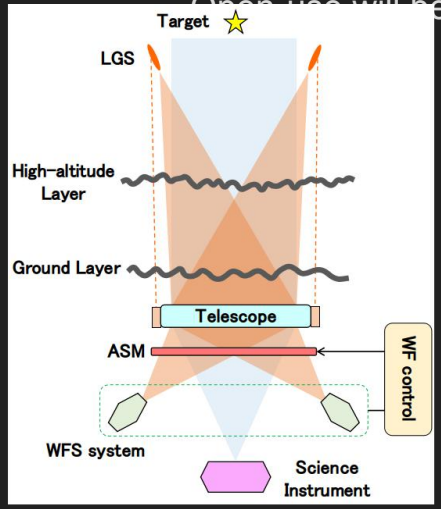


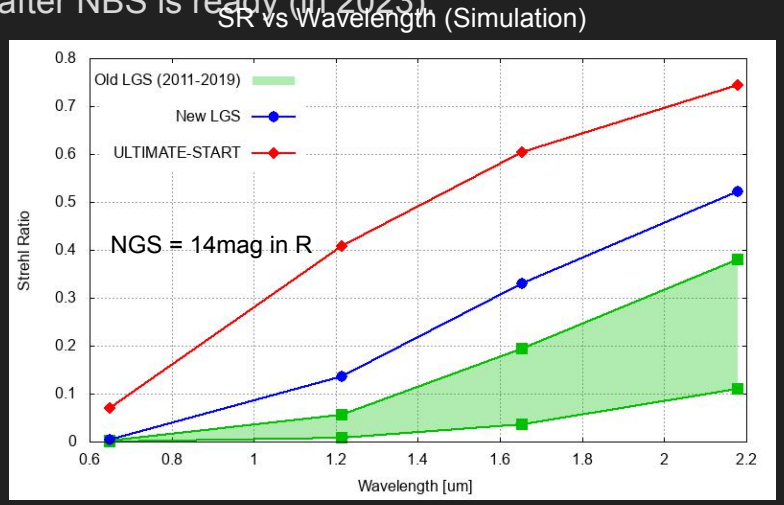


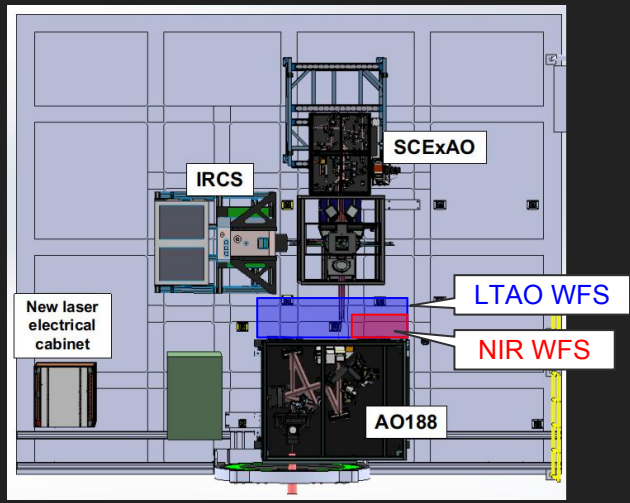
See poster [p02]

Phase 2 : ULTIMATE-START LTAO system

- Laser Tomography AO mode (LTAO)
  - Tomographic wavefront control with 4 LGSs and 4 WFSs
  - Much better performance compared to single-LGS AO mode (especially at visible wavelength)
- Install a LTAO WFS unit between AO188 and Namyth beam switching system. Reuse 64x64 DM and low-order WFS in AO3K. Modify LLT to split a laser beam to 4 beams.
- Engineering observation without Nasmyth beam switcher and science instruments will start in 22A. Open use will be after NBS is ready (in 2023).







Phase 2 upgrade

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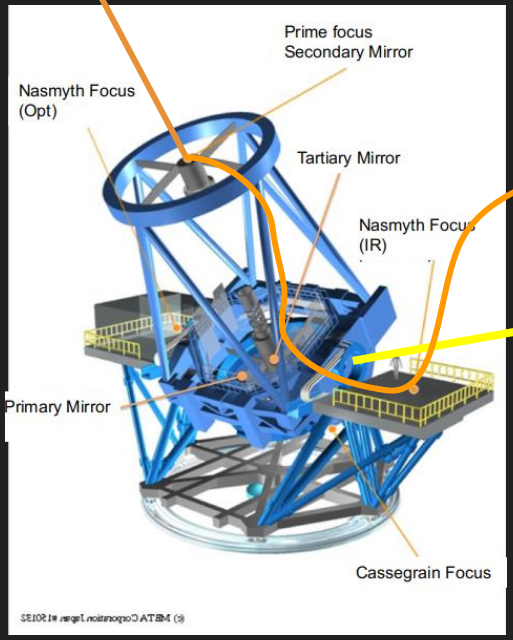
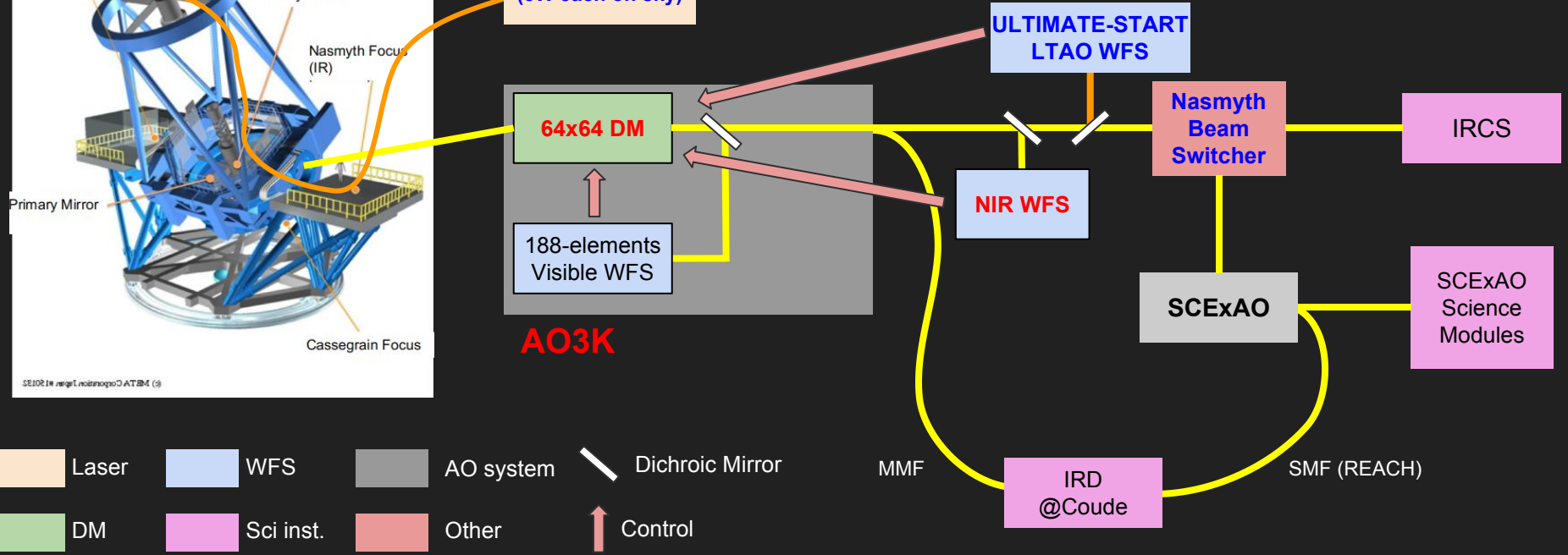
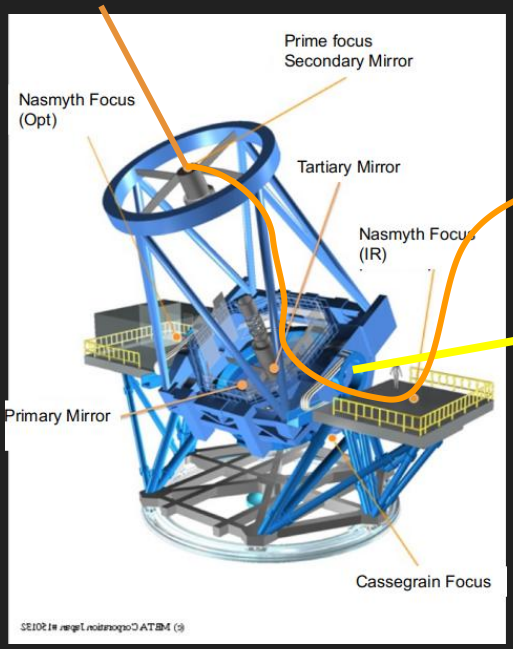
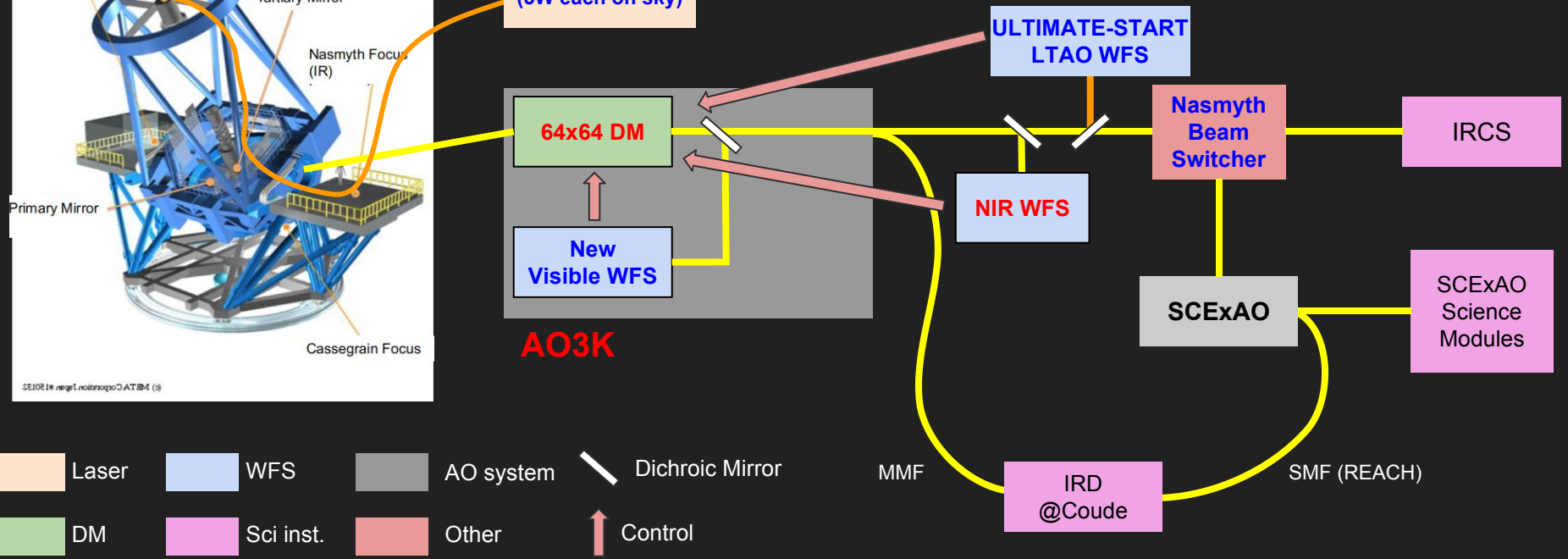




Phase 2 upgrade

- Install a Nasmyth beam switcher
- ULTIMATE-START LTAO system
  (LTAO WFS unit and four beam laser system)
- Visible WFS upgrade in AO3K





Technical demonstration for ULTIMATE and TMT-PSI

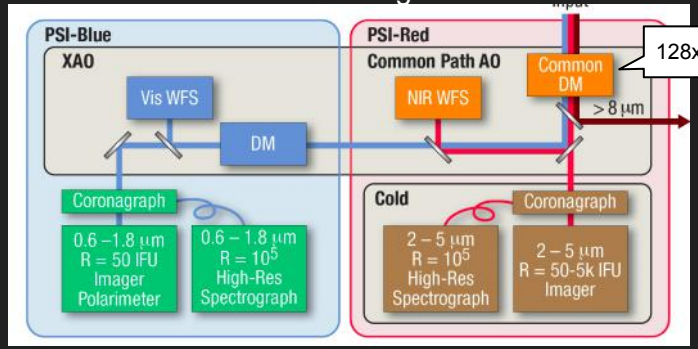
ULTIMATE-Subaru GLAO and LTAO system

- ULTIMATE-START is a precursor for ULTIMATE-Subaru to demonstrate the key technology for GLAO and LTAO systems
  - Multiple LGS system, Multiple WFS system, tomography, real-time control system

TMT-PSI (High-contrast imaging at TMT)

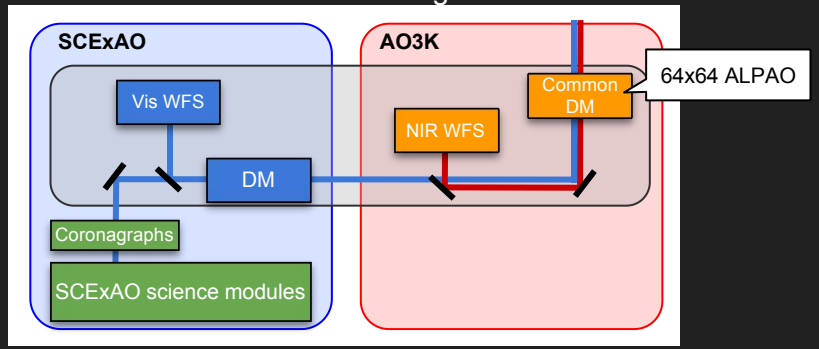
- PSI-blue (ExAO in visible wavelength) is still very challenging part
- AO3K+SCExAO will be the scale-down testbed to develop technologies for PSI-Blue (See poster [p07])
- Several developments for high-contrast observation are ongoing with SCExAO (See poster [p15], [p18], [p31])

TMT-PSI configuration



Scale down

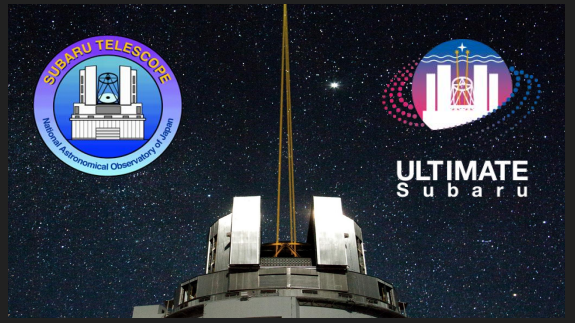
AO3K+SCExAO configuration



Summary

Phase 1

- 22W new laser guide star system (21B~)
  - SR > 0.5 in K
- NIR WFS and 64x64 DM (S22B~)
  - Wavefront control in NIR wavelength
  - Extreme AO performance (AO3K)



Phase 2

- Nasmyth IR beam switcher (sometime in 2022)
  - Easy and flexible instruments selection behind AO188
- ULTIMATE-START LTAO system (in 2023)
  - Good AO correction in visible wavelength with LGSs
- Visible WFS upgrade in AO188