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

[p07] Prototyping TMT exoplanet imaging instrumentation at Subaru Telescope

[p15] SCExAO: status of the instrument, testbed and system-level demonstrator for PSI

[p18] Scalable, spectrally dispersed and multi-baseline nulling interferometry with photonic-based technology: the GLINT instrument

[p19] Subaru Laser Guide Star Upgrade: Current Status and Schedule toward the Open Use

[p31] FIRST, a Pupil-Remapping Fiber interferometer at the Subaru Telescope : Results and Future plans

Akiyama Masayuki
Olivier Guyon
Julien Lozi
Marc-Antoine Martinod
Yosuke Minowa
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

AO188

- 188-elements DM
- 188-elements Visible WFS

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

Laser
- WFS
- AO system
- DM
- Sci inst.
- Other

Dichroic Mirror

Control
Phase 1
Phase 1 upgrade

Laser system
single beam
0.4W on sky
(Decommissioned)

188-elements
DM

188-elements
Visible WFS

IRCS

SCExAO

Science Modules

IRD @Coude

SMF (REACH)

AO188

AO system
Dichroic Mirror
Control

Laser
WFS
AO system
Sci inst.
Other

Primary Mirror
Nasmyth Focus (Opt)
Primary Mirror
Nasmyth Focus (IR)
Tertiary Mirror
Cassegrain Focus
Prime focus Secondary Mirror

188-elements
DM

Laser system
wavelength
0.4W on sky
(Decommissioned)

Control
Phase 1 upgrade

- Install a new bright laser system

Laser system single beam (20W on sky)

AO188

188-elements DM

188-elements Visible WFS

IRCS

SCExAO

SCExAO Science Modules

IRD @Coude

SMF (REACH)

MMF

Dichroic Mirror

Control

Laser

WFS

AO system

DM

Sci inst.

Other

Primary Mirror

Nasmyth Focus (Opt)

Tertiary Mirror

Nasmyth Focus (IR)

Cassegrain Focus

Prime focus Secondary Mirror
Phase 1: New laser system

- Much better AO performance, thanks 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

LGS performance (Simulation & on sky)

Performance degradation (from 2011 to 2019)

See poster [p19]
Phase 1: New laser system

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Mechanical design of the laser relay system

See poster [p19]

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)

AO188

188-elements DM
188-elements Visible WFS

IRCS
SCExAO
SCExAO Science Modules
IRD @Coude
SMF (REACH)

Laser system single beam (20W on sky)
Phase 1 upgrade

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

AO188 → AO3K

+ Laser system single beam (20W on sky)
+ 64x64 DM
+ 188-elements Visible WFS
+ NIR WFS

Control

AO system

DM

WFS

Sci inst.

Other

Laser

IRCS

SCExAO

SMF (REACH)

IRD @Coude

MMF

Dichroic Mirror

Other
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

User can select appropriate WFS

- Higher resolution = ExAO performance!!
  - Optimize WFS resolution depending on NGS brightness
- Lower resolution = AO188 performance

Visible Curvature WFS (188) → NIR Pyramid WFS
Phase 2
Phase 2 upgrade

Laser system single beam (20W on sky)

64x64 DM

188-elements Visible WFS

NIR WFS

AO3K

IRCS

SCExAO

Science Modules

IRD @Coude

SMF (REACH)

Dichroic Mirror

Control

Laser

WFS

AO system

DM

Sci inst.

Other

MMF
Phase 2 upgrade

- Install a Nasmyth beam switcher

Laser system
- single beam
- (20W on sky)

AO3K

64x64 DM

188-elements
- Visible WFS
- NIR WFS

Nasmyth beam switcher

IRCS

SCExAO
- Science Modules

IRD @Coude

SMF (REACH)

Laser

DM

WFS

AO system

Sci inst.

Other

Dichroic Mirror

Control

MMF
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.
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

IRCS

SCExAO

SCExAO Science Modules

IRD @Coude

SMF (REACH)

AO system

Dichroic Mirror

Control

Laser

WFS

DM

Sci inst.

Other

MMF
Phase 2 upgrade

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

Laser system single beam (20W on sky) or four beam (5W each on sky)

Laser system diagram:
- Nasmyth Focus
- Secondary Mirror
- Tertiary Mirror
- Nasmyth Focus (Opt)
- Primary Mirror
- Cassegrain Focus

AO3K diagram:
- 64x64 DM
- 188-elements Visible WFS
- NIR WFS
- ULTIMATE-START LTAO WFS
- Nasmyth Beam Switcher
- IRD @Coude
- IRCS
- SCExAO Science Modules
- SMF (REACH)
- MMF
- Dichroic Mirror
- AO system
- WFS
- Laser
- DM
- Sci inst.
- Other
- Control
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 Nasmith beam switcher and science instruments will start in 22A. Open-use will be after NBS is ready (in 2023).

![SR vs Wavelength (Simulation)](image)
Phase 2 upgrade

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

Laser system - single beam (20W on sky) or four beam (5W each on sky)

AO3K

64x64 DM

188-elements Visible WFS

ULTIMATE-START LTAO WFS

Nasmyth Beam Switcher

NIR WFS

SCExAO

IRCS

SCExAO Science Modules

IRD @Coude

MMF

SMF (REACH)

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Laser

DM

Sci inst.

AO system

WFS

Other

Dichroic Mirror

Control
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

- 64x64 DM
- New Visible WFS
- Laser system single beam (20W on sky) or four beam (5W each on sky)
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])

![Diagram of TMT-PSI configuration and AO3K+SCExAO configuration]
Subaru Users Meeting FY2020, March, 3-5, 2021

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