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Laser Guide Star Facility for LTAO and GLAO at Subaru Telescope

In this paper, we present a laser guide star facility (LGSF) aspect of the upcoming laser tomography adaptive optics (LTAO) and ground layer (GL) AO systems at Subaru Telescope. For the LTAO system, a TOPTICA laser will be split into four beams and launched all together from one center-launched laser launch telescope (LLT). For the GLAO system, we will use one more TOPTICA laser, split each into two, and launch them by four separate LLTs from the center section of the telescope to construct a wide asterism. We expect to install the first TOPTICA laser in a single-beam configuration for single conjugated (SC) AO in 2020, a four-beam configuration for LTAO in 2022, and a wide-asterism configuration for GLAO in 2025.

Introduction

- **Subaru's AO facility**
  - ファーストライト 36 elements in 2000
  - 188 elements in 2006
  - Laser guide star facility (LGSF) が追加される (2011)

⇨すばる望遠鏡のAOシステムにlaser-tomography (LT) and ground-layer (GL) AO モデルを追加する(ULTIMATE-START, ULTIMATE-Subaru)

- **Laser guide star**

地上からレーザーを照射して作る人工的なガイド星
地球大気の中間層 (高度 90 - 100 キロメートル付近) に存在するナトリウム原子の層 に波長589 nmのレーザーを照射することで、レーザーによって励起されたナトリウム原子が発光する現象を用いる

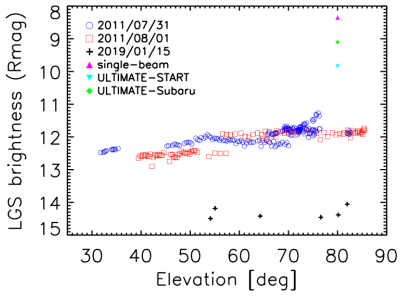
Background

LGSの明るさの大幅な劣化 (2011→2019)
2011 : 4W (LT) , R=10.7 on sky
2019 : 0.4W (LT) , R > 14 on sky

- レーザー、リレーファイバーの劣化
- すばる望遠鏡の鏡の劣化
- メンテナンスの頻度が増える

→2018年より**LGSF upgrade project**
- 協力かつ操作が簡単なTOPTICAレーザー

→ LGSの明るさ R< 8.5 on sky (シングルビーム)



ULTIMATE-START

すばる望遠鏡でマルチレーザー/WFSシステムを実証する
ULTIMATE-SUBARU のマイルストーン的プロジェクト

- TOPTICAレーザーを四つに分割、一つのLLTから打ち上げる
- アステリズムはr = 5" to 15" で調整できる

ULTIMATE-SUBARU

2025年以降のすばるの3大広域観測装置の一つを開発するプロ ジェクト

- 可変副鏡を用いたGLAOを取り入れた新しいAOシステム
- 広視野IRイメージャー

GLAO

- ２つのTOPTICAレーザーを四つに分割、４つのLLTから打ち上げる
- アステリズム D = 4' - 20' on sky

すばる望遠鏡 LGSFのアップグレード

1. single conjugated AO (SCAO)用の強力なシングルビーム構成
2. LTAO用の狭い4ビーム構成
3. GLAO用の広い4ビーム構成

Table 1. Configuration summary

	SCAO	LTAO	GLAO
Number of LGS	1	4	4
Number of laser	1	1	2
Power per beam	> 20 W	> 5 W	> 10 W
On-sky brightness (Rmag)	< 8.5	< 10.0	< 9.25
Number of LLT	1	1	4
LLT location	Center launch	Center launch	Side launch
Asterism rotation	N/A	Fixed with respect to sky	Fixed with respect to telescope
Asterism radius	N/A	Adjustable bertween 5" to 15"	2', 3', 5', 10'
WFS system	Current curvature WFS in AO188	Additional 4 SHWFSs behind AO188	New 4 SHWFSs for GLAO system
Expected first light	2020	2022	2025

SCAO

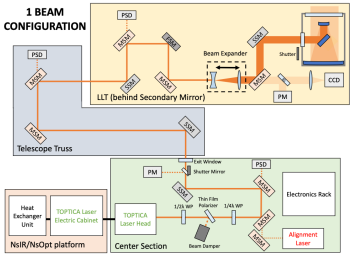


Figure 2 Single-beam configuration for SCAO. The system can be split into four sections according to the locations (NsIR, CS, Truss, and LLT) along the telescope.

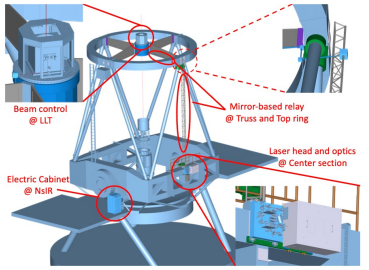


Figure 3 CAD model of Subaru Telescope and new LGSF components at NsIR, CS, TR, and LLT.

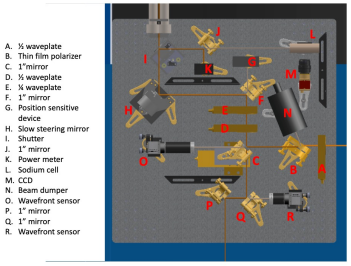


Figure 4 Diagnostic bench at CS. The power and polarization are controlled by WPs and polarizer while the beam power, wavelength, and quality are monitored and tuned by a Na cell, PM, and WFSs.

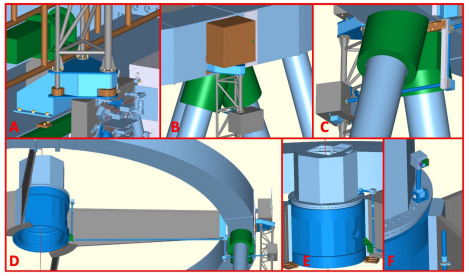


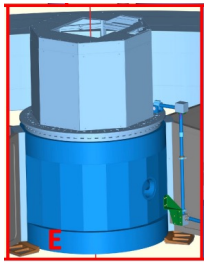
Figure 5 Zoomed images of our new relay structure at different locations. (A) Interface between the diagnostic bench and the relay truss at CS. (B) Front side of TR looking from outside to inside. (C) Front side of TR looking from inside to outside. (D) TR in a wide field view. (E) Secondary mirror and LLT. (F) Lever system for removable LLT.

LLTの主要コンポーネント

- 高速ステアリングミラー (FSM)
- beam expander (BE)

ビームエキスパンダー(BE)

シングルビーム、４ビーム両方の構成で動作する設計



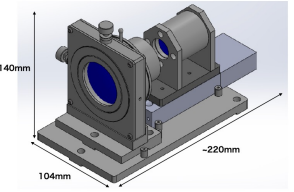


Figure 6 Our custom-made BE when it is mounted. After considering requirements from both single- and four-beam configurations, our BE consists of three lenses on a translation stage whose Gaussian magnification is 6.

LTAO

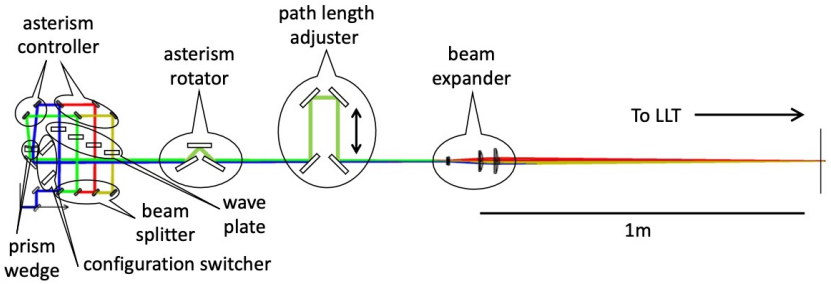


Figure 7 Conceptual optical design of a multi-beam configuration for LTAO. Descriptions of different components are summarized in Table 2.

Table 2. Optics in LLT enclosure for four-beam configuration

COMPONENTS	DESCRIPTION
Configuration switcher	Switchers 4- or 1-beam configuration by inserting/removing mirrors
Beam splitter	Splits the laser into four beams
Wave plate	Controls polarization of each beam
Asterism controller	Adjusts separation of beams from 10” to 30” on sky
Prism wedge	Shrinks beam separation to shorten optical path
Asterism rotator	Rotates the position of the beams on sky for WFSs
Path length adjuster	Adjusts optical path lengths for different beam separation
Beam expander	Expands all four beams by a factor of 6 at once

GLAO

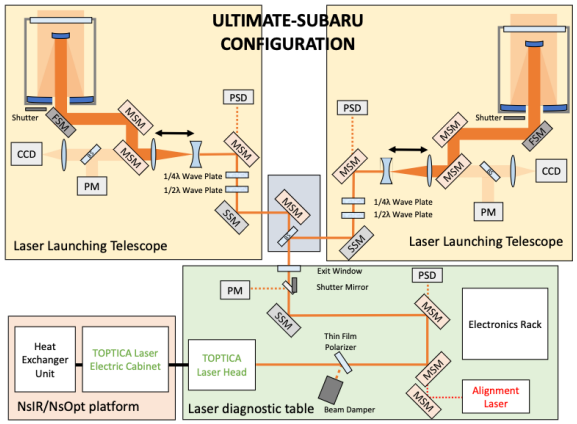


Figure 8 ULTIMATE-configuration for GLAO mode. This is the final stage of many upgrades and is used with a brand new GLAO system and a brand new wide-field imagers developed under ULTIMATE-Subaru project.

- ULTIMATE 構成

TOPTICA laser × 2
→レーザーをそれぞれ二つに分割
→4 台のLLTから別々に発射

- レーザー ~ 10 W
- LGS： R < 9.25
- 広いアステリズムを得るため、四つのLLTが必要