The laser guide star facility for Subaru Telescope

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ABSTRACT

The purpose of this paper is to report on the current status of developing the new laser guide star (LGS) facility for the Subaru LGS adaptive optics (AO) system. Since two major R&D items, the 4W-class sum-frequency generating laser[1] and the large-area-core photonic crystal fiber,[2] have been successfully cleared, we are almost ready to install the LGS facility to the Subaru Telescope. Also we report the result for LGS generation in Japan.

Keywords: adaptive optics, laser guide star, photonic crystal fiber, all-solid state laser, sum-frequency generation

1. INTRODUCTION

The laser guide star (LGS) facility for Subaru telescope is one of the major subsystem of Subaru LGS AO system.[3] We have reported the development of Subaru laser guide star adaptive optics system with 188 elements since 2002. (See references 4, 5, 6, 7, 8, 9.) The LGS facility consists the following major subcomponents.

1. A 4.5W Quasi-CW mode-locked sum-frequency generating (SFG) 589 nm laser.[1]
2. Diagnostics system for laser power, beam quality, polarization and wavelength.[1]
3. Solid-core photonic crystal fiber (PCF) cable for laser beam relay.[2]
4. Laser clean room.
5. Laser launching telescope.

You will find the layout of Subaru LGS AO in Fig. 1. The SFG laesr and the laser diagnostics system are installed in the laser clean room, which is mounted on Nasmyth platform. Laser beam is projected from the laser launching telescope mounted behind the secondary mirror. The PCF cable transfers the laser beam from Nasmyth platform to the laser launching telescope. The length of the PCF cable is 35 m. In this paper, I'd like to introduce the current status of subcomponents, and the laser projection experiments in Japan.

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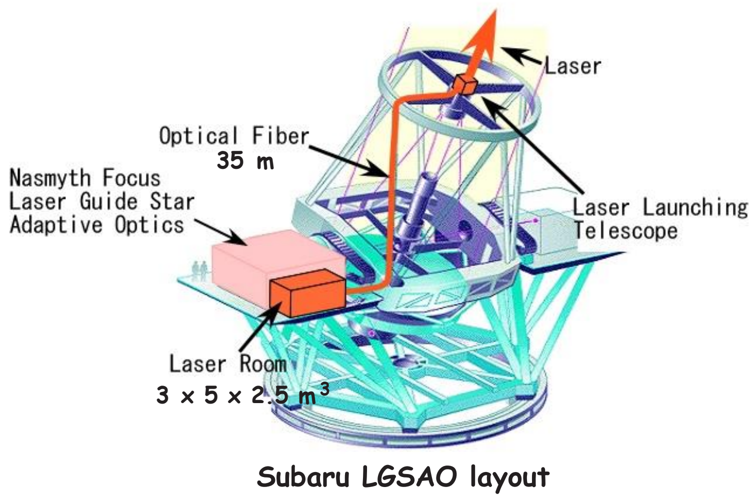

Figure 1. The layout of Subaru laser guide star adaptive optics with 188 elements.

2. SUBCOMPONENTS FOR LASER FACILITY

2.1. Laser and Laser Diagnostics System

We chose all solid-sate laser to generate a coherent light source at the wavelength of 589nm. Thank to the rapid growth of laser technology especially in converging the laser wavelength with non-linear crystal, we succeeded to manufacture the high power sum frequency generating laser with using two different Nd:YAG laser. Currently we achieved 4.5W output in mode-locked pulse operation within 1.3% stability for 8 hours. The photographs and technical details of 589nm laser are presented in Saito et al.[1] The basic design for laser diagnostics system is also shown in Saito et al.[1]

2.2. Photonic Crystal Fiber for Laser Beam Relay

Laser beam should be relayed from laser clean room to the laser launching telescope with minimum loss and minimum degradation of beam mode. We selected a photonic crystal fiber (PCF) to relay the laser beam. Our requirement for relay fiber is summarized in Table. 1.

Table 1. Requirement for relay fiber.

Items	Requirement
Cutoff wavelength	$< 589.159\ nm$
Input laser power	$> 4\ W$
Transfer beam mode	Gaussian beam ($M^2 < 1.1$)
Mode field diameter	$> 14\mu m$
Fiber end treatment	AR coating ($< 0.2\%$)
Fiber length	35 m
Transmission loss	$< 15\ dB/km$

Mitsubishi Cable Industry succeeded to fabricate the PCF cable within our specification. (See Figure 2) The cable contains 6 PCFs. They achieved the transmission loss of 10 db/km, finally. We estimated the lower limit

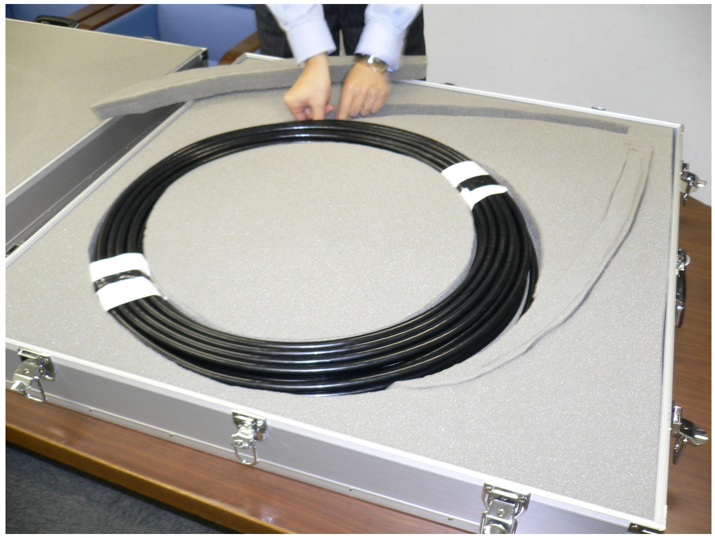

Figure 2. The photograph of PCF cable in real use on the Subaru Telescope.

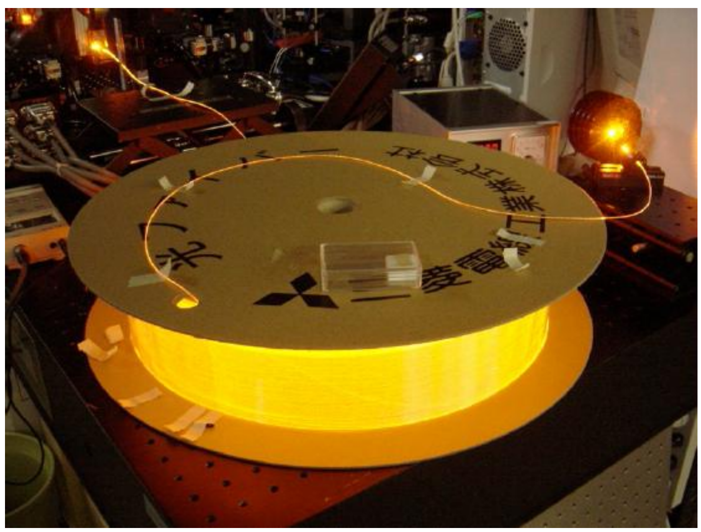

Figure 3. The experiment of laser input into the prototype PCF.

of threshold level of a non-linear stimulated scattering in the PCF to be more than 30 W, when we use our mode-locked quasi-continuous wave sum-frequency laser. The details of evaluating and testing these PCF are reported in Ito et al.[2] (Figure 3).

2.3. Laser Clean Room

We locate the laser clean room on the Nasmyth floor. You can see the arrangement of AO optical bench, AO instruments (IRCS or HiCIAO) and laser clean room on the Nasmyth floor in Figure 4. The total size of the laser room is 3 m x 5 m x 2.5 m. Laser clean room has two chambers. First you can enter the anterior chamber, where the control electronics for laser system and diagnostics system and chillers are installed. The size of this chamber is 1.7 m x 2.9 m x 2.5 m. The clean chamber, next to the anterior chamber, is actually a clean room where the laser system is placed. The air temperature in this chamber is controlled at 15 degrees Celsius and stabilized within 1 degrees Celsius. This size is 3.15 m x 2.9 m x 2.5 m. Cleanliness of the chamber is controlled

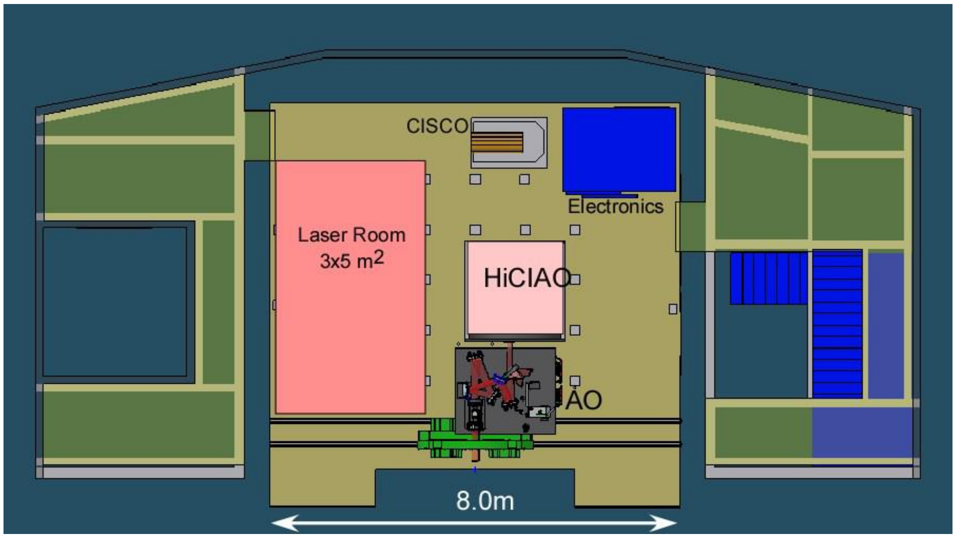

Figure 4. Location of laser clean room at Nasmyth Floor.

Figure 5. The photograph of the top view of the laser room.

less than 10000. If we let the chamber desolate, the cleanliness becomes less than 1000. Humidity is not actively controlled, because humidity at Nasmyth platform, where the air is cooled down around 0 to 5 degree Celsius in daytime, does not exceed 90% since we have started to monitor it for 18 month.

We have inspected the laser room during a trail assembly experiments in Japan. (Figure 5 and Figure 6.)

2.4. Laser Launching Telescope

Laser launching telescope (LLT) is mounted behind the secondary mirror. The design of LLT is a copy from ESO LLT design[10].[11] The LLT has already manufactured and tested by the Space Business Unit of Galileo Avionica (Italy). The summary of optical design are shown in the Table 2.

3. LASER PROJECTING EXPERIMENT IN JAPAN

Laser projection demonstration has been made since May 2005 at the Institute of Physical and Chemical Research (RIKEN), about 10 km away from the center of Tokyo. We use prototype SFG laser located at the experimental

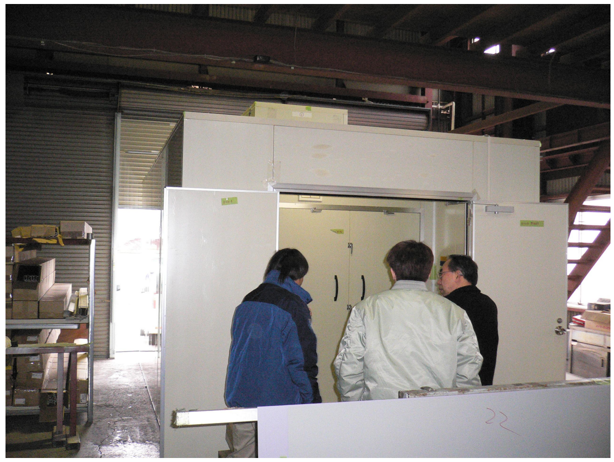

Figure 6. The photograph of the front view of the laser room.

Table 2. Specification of laser launching telescope.

Items	Requirement
Telescope configuration	On axis two mirror beam expander
Exit pupil diameter	500 *mm*
Angular magnification	12.5
Entrance pupil	On the secondary mirror, 40 *mm*
Field of view	2 *arcmin*
Total wavefront error	$<$ 61 *nm rms* (full aperture)
Operating zenith angle	$<$ 60 *degrees*

laboratory in the laser research building, which generates around 1 W output power. We use 30m-length prototype PCF cable to relay the laser beam from the laboratory area to the outside of the building. The laser beam is projected from 15cm-diameter refractive telescope, which is placed in the back yard of the building. (Figure 7.) We use 20cm-reflective telescope, which was set about 10 m away from the laser projecting telescope to obtain the CCD image of laser guide star (LGS). Total throughput of PCF, which take into account the coupling loss and the fiber transmission loss, is about 60%. Estimated brightness of LGS is about 13.9 equivalent magnitude at V-band at the zenith angle of 22 degrees. (See Figure 8.) We roughly estimate that LGS brightness at Mauna Kea might be about 11 magnitude at zenith for 4.5 W laser.

4. SCHEDULE

Laser, laser diagnostics system, relay fiber and laser clean room have been already shipped from Japan to Hilo, and it will arrive in June. Laser launching telescope is almost ready to ship from Italy to Hilo. After the fundamental and assembling test in Hilo, we will bring up the laser facility to the summit in September 2006.

The first laser launching test will be scheduled on October, 2006. We estimated that it takes about half year to achieve the first closed loop on the laser guide star. It would be in the spring of 2007.

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Figure 7. Laser projection experiment in Japan. Projected output power in the air is about 0.5W. The beam size is about 10 cm

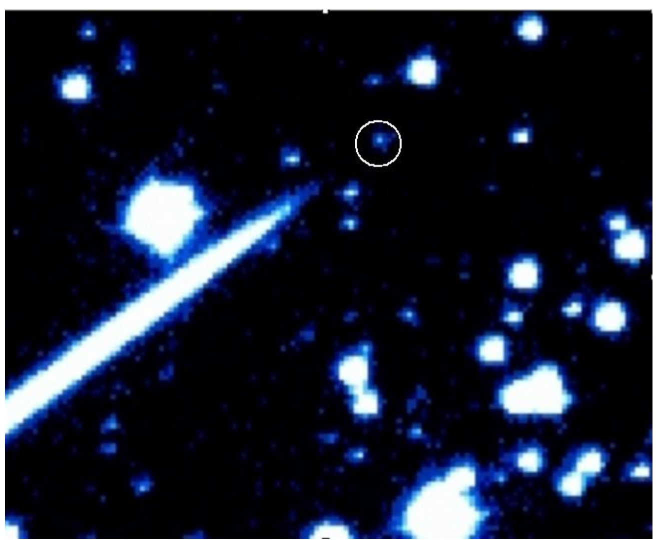

Figure 8. Image of LGS. Estimated brightness of LGS is about 13.9 equivalent magnitude at V-band.

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