Natrium-Teide experiment. Sodium layer observations at Teide Observatory (Canary Is.)

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Abstract. With the aim of characterizing the atmospheric Na layer, the Teide Observatory facilities have been used in the last years to carry out a long term monitoring experiment on LGS generation by low power laser excitation. The LGSs are generated by a Rodamine 6G Dye tunable laser launched from the Optical Ground Station with a typical output power of 400 – 500 mW. The LGS images are obtained in a bistatic configuration with a baseline of 165 m. The experiment has been improved in several aspects in order to boost the Na photon flux return. The natrium-Teide experiment has generated a dataset of more than 400 images of Na LGS traces obtained in 37 nights. The main results are going to be published soon.

1. Introduction
Laser Guide Stars -LGS- has been widely proposed to extend the domain of stable operation for Adaptive Optics (AO) systems in large telescopes. The overall Strehl ratio achieved by an AO system is depending on all errors involved in the wavefront sensor function. LGSs contribution to this error directly depends upon two main aspects, the LGS spot profile and the Signal to Noise Ratio (SNR). Therefore, an accurate characterization of the Na layer is imposed. Three main aspects must be dealt with such a characterization: the abundance of atoms, the layer altitude and thickness (that is directly related with the elongation projected due to the perspective and the finite thickness of the layer) and the stability of the layer.

With the aim of characterizing the atmospheric Na layer, the Teide Observatory facilities (≈ 2400m, 16°30.5′ W, 28°18.1′ N) have been used in the last years to carry out a long term monitoring experiment on LGS generation by low power laser excitation: the natrium-Teide experiment. Details on the experiment have been best explained by Chueca et al. [1]. We employ the 1 m Optical Ground Station1 (OGS) as launching telescope (see figure 1), while the backscattered photons are received in the 0.8 m IAC80 telescope2, 165 m away, in a bistatic configuration.

1 The Optical Ground Station was built as part of European Space Agency research in the field of inter-satellite optical communications (http://www.iac.es/telescopes/pages/en/home/telescopes/ogs.php?lang=ES)
2 http://www.iac.es/telescopes/pages/en/home/telescopes/iac80.php?lang=ES
Figure 1. The Optical Ground Station while launching the Rodamine 6G dye tunable laser onto the atmosphere for the generation of a Na LGS spot.

2. Methodology

The OGS is equipped with a Coudé room which facilitates laser operations. The LGS are generated by a Rodamine 6G dye tunable laser (Coherent 899 − 21) pumped by a Coherent Verdi Solid-State Green laser (15 W, 532 nm). The tuning to the $D_2$ sodium spectroscopic line is achieved using a birrefringent filter inside the resonant cavity with a bandwidth of $\approx 10$ MHz, allowing an unique oscillation mode. The fine tuning is carried out with a pair of ethalons and the wavelength control is made splitting $\approx 2\%$ of the beam energy to a Michelson interferometer.

The beam is projected onto the mesosphere with the telescope and an off-axis optical arrangement. The typical output power is 400 − 500 mW. After a resonant scattering process with the Na atoms in the Mesosphere ($\approx 90$ km), the LGS is imaged with the CCD of the 0.8 m IAC80 telescope, in a bistatic configuration with a baseline of 165 m (see figure 2). We use a 2 nm narrow BW filter and exposure times of 300 sec. For the basic astronomical reduction we have developed a pipeline based on IRAF. The height determination is obtained by triangulation. As the telescope pointing information has not enough resolution, natural star trails are used to obtain the zenith angle. The detailed equations of the geometry of the system for absolute height determination are in Castro-Almazán et al. [2]. The Na abundance is obtained with relative photometry. We obtain images of the natural star trails in the R Johnson band for calibration and we use Sextractor.\(^3\)

\(^3\) www.astromatic.net/software/sexttractor
2.1. Experiment improvements

The experiment has been improved in several aspects in order to boost the Na photon flux return, for example:

- Increasing the pumping efficiency from Ar laser (25 W, 514 nm) to High-Power Optically Pumped Solid State (Verdi, 15 W, 532 nm).
- Reducing the optical elements in the launching path.
- Changing the launching optical configuration from ‘on axis’ to ‘off axis’ to avoid the secondary mirror obscuration (see figure 3).

Figure 2. The bistatic configuration used for the experiment, launching to the zenith.

Figure 3. The effect of changing the launching from ‘on-axis’ configuration to ‘off-axis’. The secondary obscuration is avoided, improving the photon flux return. An optical arrangement was designed to collimate the beam axis on the Mesosphere level.
3. Results
The natrium-Teide experiment has generated a dataset of more than 400 images of Na LGS traces obtained in 37 nights. The main results are going to be published soon, and will be auxiliary data for the incoming Laser Guide Star for AO at Gran Telescopio Canarias (GTC) in the neighbouring Roque de los Muchachos Observatory (≈ 140 km away). The figure 4 show three typical images obtained with the experiment with remarkable phenomena, as sporadic layers [3] and enhanced layers [4].

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References
[1] Chueca S, Fuensalida J, Alonso A and Reyes M 2004 Optics in Atmospheric Propagation and Adaptive Systems VII (Proc. SPIE vol 5572) ed Gonglewski J and Stein K pp 392–399
[2] Castro-Almazán J, Fuensalida J, Alonso A and Chueca S 2008 Ground-based and Airborne Telescopes II (Proc. SPIE vol 7012) ed Stepp L and Gilmozzi R pp 701240–1–12
[3] Simonich D, Clemesha B and Batista P 2005 Adv. Space Res. 35 1976–1980
[4] Clemesha B 1990 Adv. Space Res. 10(10) 10(59–70)