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Experimental test of laser beam propagation with simultaneous measurements of turbulence profiles

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ABSTRACT

The experimental study of laser beam propagation in turbulence is relevant to fields such as adaptive optics and optical communications. Turbulence sensing for astronomical purposes requires a convergent laser beam adequately focused on the sodium mesospheric layer. Free Optical communications ground-to-satellite usually are based on divergent laser beams travelling partially through the atmosphere. We present several measurements of the gaussian beam radius for divergent and convergent laser beams propagated in vertical paths. The determinations were carried out at the Teide Observatory (Canary Islands) from the analysis of Rayleigh scattering. The turbulence profile was simultaneously measured with a SCIntillation Detection And Ranging (SCIDAR) instrument. This way, we analyse the influence of the different turbulence layers in the focusing problem through the empirical relation between the beam waist radius and the intensity of the turbulence. We present the experimental set-up, the first results of the experiment and the plans to conduct a statistical study in the future.

Keywords: laser beam propagation, atmospheric turbulence, Canary Islands observatories

1. INTRODUCTION

Atmospheric turbulence due to random variations in the refractive index of the atmosphere modifies the radius of a laser beam as compared to free-space propagation. Propagation of convergent and divergent beams is important in the fields of free-space optical communications and Laser Guide Star (LGS) generation for adaptive optics. In optical communications, the knowledge of turbulence effects is critical to achieve high data rates with low bit error rates. In astronomical adaptive optics, the fundamental principle is exciting the mesospheric sodium layer with a laser beam to get a reference source. The backscattered signal travels through the turbulence of the atmosphere, allowing to measure its effects to correct the astronomical images. The size of the LGS is basically determined by the properties of the sodium layer and the geometry of the focused laser beam. In this respect, the understanding of turbulence is critical for optimizing the quality of the artificial star.

At the IAC observatories in the Canary Islands, there are important projects in those two fields. At the Teide Observatory, the European Space Agency has built an Optical Ground Station (OGS) from where the first stable bidirectional ground-to-space laser communication links are currently being performed[7] with ARTEMIS satellite. At the Observatorio del Roque de los Muchachos (ORM), Durham University is carrying out a program to generate a Rayleigh scattering star[11], and several other telescopes are planning to install LGS systems to correct atmospheric turbulence, the most conspicuous being the 10-m class telescope Gran Telescopio de Canarias (GTC).