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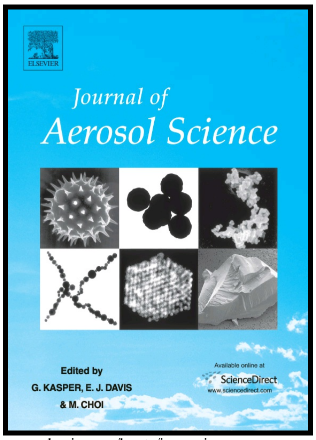

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A laboratory experimental study on laser attenuations by dust/sand storms

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Abstract:

In this paper, the laser beam attenuation by sand/dust storms is experimentally investigated under controlled lab conditions for 5 laser wavelengths, i.e., 405 nm and 532 nm in visible band and 850 nm, 1064 nm and 1550 nm in near infrared band. It is found that the attenuation coefficient of the laser links exponentially decreased with the increase of the visibility of dust/sand storms mimicked in a glass chamber with mixed-size sand samples. The longer the laser wavelength, the lower the attenuation coefficient under the same visibility, e.g., when the visible range is 0.1 km, 0.5 km and 1 km, the attenuation coefficient of the laser links with the wavelength 405nm is 174±10.9 dB/km, 33.7±4.7 dB/km and 17.7±1.6 dB/km, while the attenuation coefficient of the laser links with the wavelength 1550 nm is 126±10.7 dB/km, 23.7±10.8 dB/km and 9.6±2.5 dB/km, respectively. In addition, it is found that the attenuation decreases with increasing effective particle size under a given visibility. Furthermore, based on the experimental results and Kruse model, an improved model for the calculation of laser beam attenuation by sand/dust storms, which is a function of both laser wavelength and effective particle size of the sand/dust storms, is proposed.

Keywords: Attenuation coefficient; Improved attenuation model; Dust/sand storms; FSO communication; Scattering/absorption measurements.

1. Introduction

Lasers have wide applications in various areas [1], such as free-space optical (FSO) communication and lidar [2-5]. Many studies have shown that laser beams can be affected seriously by weather conditions, such as fogs and rains [3, 6-9]. On the other hand, dust and sand storms occur frequently in arid and semi-arid areas, such as in the Middle-East, North-Africa, North-China and Australia during spring, winter or early summer [10]. Sand/dust storms always carry fine-grained sand/dust particles [11], which absorb and scatter laser light [12] and cause the attenuation of laser beams.

Ghassemlooy *et al.* investigated the performance of the FSO links through laboratory experiments, and found that the attenuation of FSO links in sand/dust storms was comparable to that in fog [13]. Esmail *et al.* studied the attenuation of laser beams with a wavelength of 1550 nm in dust storms, where the average particle diameter was 4 μm, and proposed an empirical model for the calculation of the laser beam attenuation as a function of visibility [12], which was independent of particle sizes and the wavelength of lasers. However, Libich *et al*. studied the effect of turbulence and aerosol on FSO and found that the size of aerosol particles has a profound effect on FSO Links [14]. Furthermore, the particle size of dust/sand storms are much larger than that of aerosol particles, and the visibility in dust/sand storm is inversely proportional to the effective particle size [15]. Therefore, the attenuation of laser beams in dust/sand storms should depend not only on laser wavelength, but also on effective particle sizes.

However, currently there are few studies that have investigated the laser beam attenuation as a function of laser wavelength and effective particle size in dust/sand storms, which was a knowledge gap to be remedied for laser applications, especially in regions where sand/dust