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Research Article

OPTIMAL ANALYSIS OF LASER BEAM PROPAGATION THROUGH DUST STORM

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ABSTRACT

Recently the image process was getting more attention to analysing the propagation of laser. In this study describes the changing of laser spot profile being dependent upon the amount of attenuation and throw simulate dust storm. Several ways used to find the intensity changing, 3D surface profile of spot, intensity spectral distribution and FFT analysing. The simulate dust storm with a particle size 53 µm has been completed by traveling light through glasses box volume was cm3 with indoor fan to move the dust during the laser pass for a 20 seconds pictures snapped of the laser spot at different time of dust storm (0, 5, 15, 25, 35, 45 and 60 minutes.

INTRODUCTION

In last decades the methods based on digital image processing of a laser spot attracts more attention in aircraft monitoring and several other applications such as interactive interfaces (LI and WU, 2014), laser guided robots (Liao *et al*., 2012; Yemei *et al*., 2011), assistive technology (Bharucha *et al*., 2009) and range measurements (Xie and Ma, 2015). Because of the some limitation in the field of aerospace, like volume, quality, installation conditions and structure, the traditional sensors are progressively replaced by non-contact measure. There are several advantages for example higher speed, richer information, and less impact on the object. The major challenges of measuring the laser spot in images in an outdoor environment obtained by a camera are attributed to uncontrolled conditions and attenuation by dust and other aerosols (Yemei *et al*., 2011; Ruike *et al*., 2007; Grabner *et al*., 2014). In order for the laser spot shaping to be effective, it is necessary to be able to measure the degree to which the irradiance pattern or spot profile has been modified by the medium. Most of the changes are become from the absorption or scattering, so that it is very important to measure how this medium attenuate the laser intensity. In general the attenuation of laser intensity in free space is defined by Beer's Lambert law (Sassaroli and Fantini, 2004)

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$$I_R = I_0 e^{-\mu X} \quad (1)$$

$$\frac{I_R}{I_0} = T(X) = e^{-\mu X} \quad (2)$$

Where Io is the initial intensity of the laser, IR is the intensity near the target, T(X) is the transmittance, X is the range of propagation and µ is the total attenuation. The attenuation coefficient has contributions from the absorption and scattering of laser photons with different aerosols and gaseous molecule in the atmosphere (4). The attenuation coefficient is made up of four parts (9):

$$\mu=\alpha\_g+\alpha\_P+\gamma\_g+\gamma\_p \quad (3)$$

where α_g, 〖α_P,γ〗 _g, and γ_p are the molecular absorption coefficient, aerosol absorption coefficient, Rayleigh scattering coefficient by molecules, and aerosol or Mie scattering coefficient respectively. When the power of visible laser is low and size of particles more than 100 nm, it is possible to ignoreα_g and γ_g so that equation 3 becomes:

$$\mu=\alpha\_P+\gamma\_p \quad (4)$$

The total atmospheric transmittance can be factored as the product of the absorption and scattering transmittances.

$$T(X) = T(\alpha)T(S) \quad (5)$$

where T(α) is the absorption transmittance, T(S) is the scattering transmittance. As showed before the attenuation of dust and atmospheric aerosols are due to Mie scattering particles, and the effective absorption of electromagnetic relatively very small comparing with Mie scattering. Hence, the scattering coefficient is taken from the visibility distance and wavelength of the incident beam. The range of visibility is related with concentration of dust as (Charlson, 1969):

$$V=7080\times C\text{^}(-0.8) \quad (6)$$

where V and C are the visibility distance and concentration of dusts respectively. Therefore, there is a direct relation between concentrations of dust and scattering coefficient due to atmospheric aerosols (Kim *et al*., 2000):

$$T\_S=\exp(((-3.91)/(7080\ C\text{^}(-0.8)\ ))\ (\lambda/0.55)\text{^}(-q)\ \ X\ ) \quad (7)$$

where λ is the wavelength and q is positive constant.

This paper describes of the laser spot profile analysis after throw in different concentration of dust and time. It introduces new concepts for profile analysis depending on image processing methods for measuring the laser spot profile. Discussion of the information that can be generated simply by viewing the spot profile, and finally, quantitative measurements are made on laser profiles.

Experimental

A He-Ne laser (λ = 633 nm) model ……. served as the CW light source. The spot profile was Gaussian with a $1/e^2$ and diameter was 5.3 mm measured using a camera type Cannon model …… in CCD mode. The distance between the front surface of the laser and the screen surface was set at 40 cm. In this experiment the laser light travel through glasses box had a volume cm^3 with indoor fan to move the dust during the laser pass for a 20 seconds. The average size of particles was 53 µm. Several pictures snapped of the laser spot at a different time of the dust storm (0, 5, 15, 25, 35, 45 and 60 minutes. The Images of spot were analyzed by ImageJ software version 1.5a and using fast Fourier transition (FFT) analysis to calculate the intensity spectrum.

RESULTS AND DISCUSSION

To know the influence of dust on the laser propagating characteristics, the laser is propagating in simulating dust storm with different time. Fig.1 shows the intensity distribution of the laser spot with distance at various times. The distance of the initial propagation is 50cm without dust. After blower works to simulate dust storm, the initial spot is attenuated due to the multiple scattering with the dust particles as showed in Fig.1 at T=0 (within a dust storm). Fig.1. The falling edge of the spot gets more attenuation because it has less intensity comparing with the center of the spot. However, the intensity of spot increases after storm ending. Mostly the spot becomes gentle, like dragging a long "tail." It can be seen that the intensity of light in the minimum increases as time increase, the maximum intensity of the spot appears at T=60 min. after ending of dust storm, the spot width is broadened gradually, and the "tail" becomes more pronounced as showed in the inset in

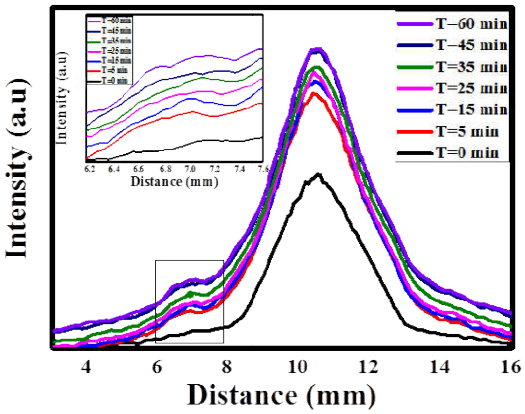

Fig.1.

The radius of spot increases because the mean free path length of photons is increasing too. Therefor number of scattering (collusions) becomes less. For high of dust concentration the paths deviate from the straight line more seriously. Then the propagation time and absorbed probability increase as displays in Fig. 2. The inset in Fig. 2 shows big difference between initial time (T=0) and the final time (T=60 min) because of decline particle distribution as showed below. The extinction confession of the dust particles are $1.798\text{x}10^{-2}$ which is calculated by Eq.2. Now depending on that, it is possible to calculate the concentration of dust regarding to the varying of intensity and the results presented in Fig.3. However from that figure it is very easy to find concentration of dust at any time or intensity without using any extra instruments or detectors.

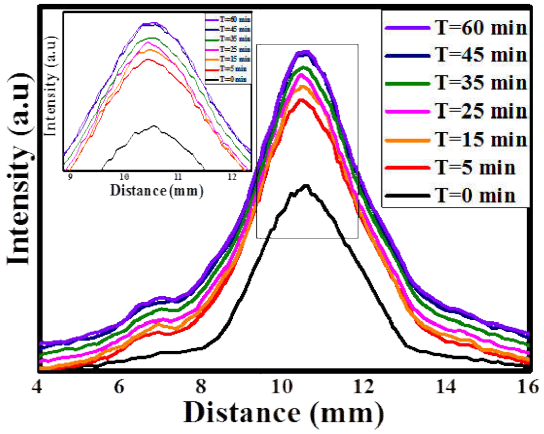

Fig. 2.

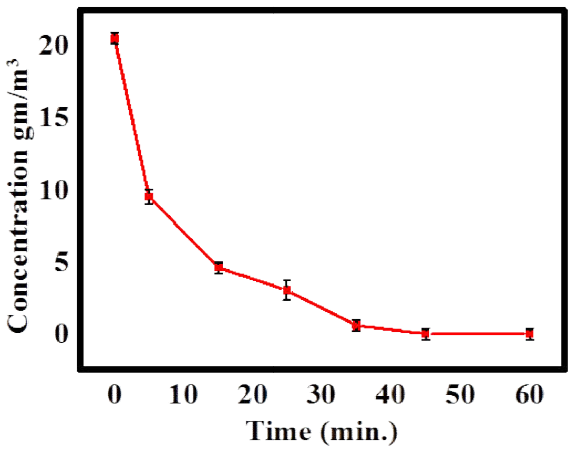

Fig. 3.

Generally, there are three types of scattering mechanism follows laser propagation in free space. First Rayleigh scattering (Bates, 1984) occurs when the atmospheric particles are much lower than the wavelength. Rayleigh scattering arises mostly of the gaseous molecules in the atmosphere14. Second and third are Mie and geometric scattering (Pavlyukh, 2004; Yang *et al*., 2007) respectively.

$$S_p = \frac{2\pi r}{\lambda} \quad (7)$$

Where S_p , r and λ are the size parameter, radius of the scattering particle and laser wavelength respectively. The size parameter varies between 0.1 and 50 for Mie scattering, and greater than 50 to the geometric scattering.

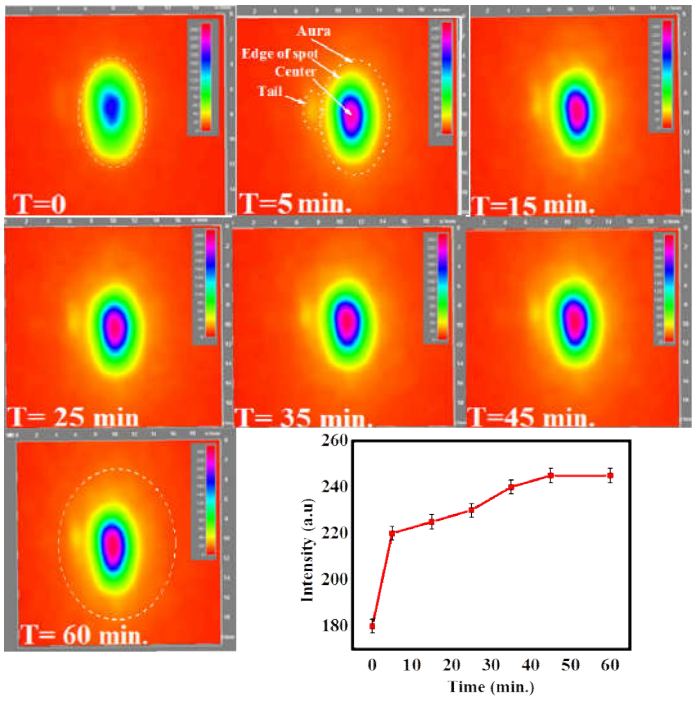

Fig.4.

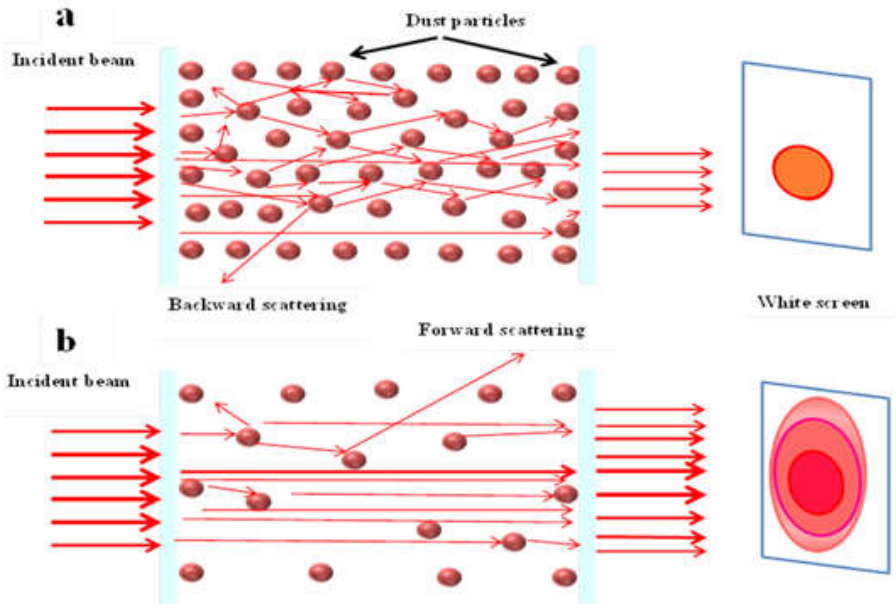

Fig. 5. Proposed model for laser scattering in dust

These types of scattering happen when the size of particle much larger than the laser wavelength. So that for the wavelength of He-Ne laser (633nm), the effect of Rayleigh scattering the total attenuation coefficient is very small comparing with other two types of scattering. To determine the type of scattering for the transmission wavelength respect to the size of particles using the following equation (Bohren, 2008).

According to equation 7 the value of size parameter is 52, therefore most of scattering is related to geometrical scattering assuming that whole particles at the same size. Through analysis images of the spot at different time of the dust storm the resulting shows clearly the intensity is divided into several areas depending on the distance from the center to the edge of the spot.

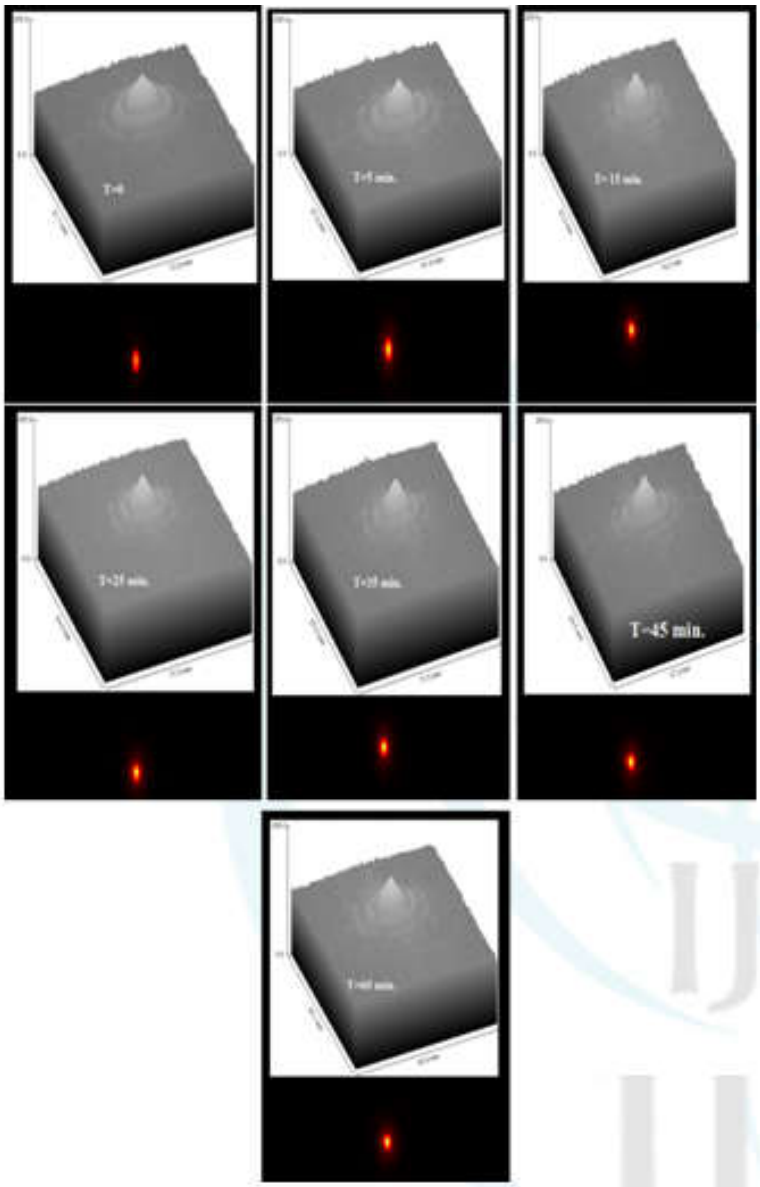

Fig.6

Fig 4 shows the result of intensity distribution in spot. The intensity is minimum and no aura appears at T=0 because of high forward scattering in the dust and/or distraction and absorbed all the weak intensities of the aged. It is notes on appearance of slight aura around the spot after five minutes at T=5 min of stopped the storm. The intensity and area of aura increase with the time increasing gradually. Generally this aura is arising from the forward scattering and decreases the geometrical scattering. Furthermore, the shape of spot not really circle and it becomes like oval due to high attenuation of dust particles. This behavior is a consensus with other work (Ready, 1997) and it is matching with the results in Fig 1 and 2. Since the majority of the scattering come from geometrical scattering. The graph in Fig. 4 shows the variation of intensity with the time of the dust storm. It is very clear to see that the intensity of the spot center increase significantly after storm stopping. It is worthy to notes that. The attenuation comes from direct collusion between the photons and aerosols and as it found before the collusions is elastic. So we proposed a model to show how the laser beam passes through the dust. Most of attenuations due to direct incident are presented in.

To understand the intensity distribution of the spots and how the laser attenuated by dust within the dust storm has been used to image process to calculate the frequency change in image. There are several ways to be done, but Fast Fourier Transform (FFT) is the best. Typically, there are different phases (frequency) of the spot of the laser due to the information resulting from the Fourier transform (Averbuch *et al*., 2006). Once transformed into the frequency space it is easy to see points or lines in the power spectrum that is created attributable to sinusoidal and linear attenuation in the original image. Fig 5 presents the results for FFT of the spots of laser at various time of storm. The peak at the centre of the plot is the total of all intensities that has more energy at high horizontal frequencies than at high vertical frequencies. At time T=0 minute, the intensity of the original spot very low and the spot becomes faint. The 3D FFT analysis of the image shows the spectrum distribution of intensity. It is noted that there are three regions of intensity and the intensity has Gaussian distribution. Furthermore, there are two vertical and horizontal lines through the centre. This is explained by the fact that the spot was attenuated d by dust in the two directions.

Fig. 5at T= 5, 10, 15, 25, 35, 45 and 60 min. shows the same trend of intensity in spite of increasing the intensity with the time increasing gradually Also, if you look carefully you can see that the diameter of a spot slightly larger than the spot at T=0. It is extremely important to see in these images there is no distortion in the original spot and the same information can get it from the images. So we can say the dust storm just effect on the intensity of the beam but not effects on the wavelength of the beam.

REFERENCES

Averbuch, A., Coifman, R.R., Donoho, D.L., Elad, M., Israeli, M. 2006. *Applied and computational harmonic analysis*, 21 145-167.

Bates, D. 1984. *Planetary and Space Science*, 32 785-790.

Bharucha, A.J., Anand, V., Forlizzi, J. Dew, M.A., Reynolds, S. and Stevens, H. 2009. Wactlar, *The American journal of geriatric psychiatry*, 17. 88-104.

Bohren, C.F., Huffman, D.R. 2008. Absorption and scattering of light by small particles, John Wiley & Sons.

Charlson, R.J. 1969. *Environmental science & technology*, 3 913-918.

Grabner, M., Kvicera, V. 2014. *Journal of Lightwave Technology*, 32 513-520.

Kim, I.I., McArthur, B., Korevaar, E.J. 2001. Information Technologies 2000, *International Society for Optics and Photonics*, pp. 26-37.

LI, R. and WU, 2014. *Video Engineering*, 3 045.

Liao, H., Noguchi, M., Maruyama, T., Muragaki, Y., Kobayashi, E., Iseki, H. and Sakuma, I. 2012. *Medical image analysis*, 16 754-766.

Pavlyukh, Y. and Hübner, W. 2004. Physical Review B, 70. 245434.

Ready, J.F.1997. Industrial applications of lasers, Academic press.

Ruike, Y., Xiange, H., Yue, H., Zhongyu, S. 2007. International *Journal of Infrared and Millimeter Waves*, 28. 181-189.

Sassaroli, A., Fantini, S. 2004. Physics in Medicine and Biology, 49 N255.

Xie, C. and Ma, H. 2015. Open *Automation and Control Systems Journal,* 7 (2015) 60-66.

Yang, P., Feng, Q., Hong, G., Kattawar, G.W. Wiscombe, W.J. Mishchenko, M.I., Dubovik, O., Laszlo, I., Sokolik, I.N. 2007. *Journal of Aerosol Science*, 38 995-1014.

Yemei, C. and ChangSha Aeronaut. J. 2011. *Vocat. Technical College*, 60-62.

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