

265nm LED mini-lidar -Theoretical Approach-

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Abstract: The LED mini-lidar is discussed to install DUV-LED device in theoretical approach. The short wavelength of 265nm is in solar blind region, and it has potential to observe the low and surface atmosphere in daytime with its handy lidar setup. In this study, the lidar system optimization is discussed for the atmosphere with small and steep spatiotemporal scale measurement in daytime with enough signal-to-noise ratio.

1. Introduction

The low atmosphere and surface atmosphere depend strongly on their ground or sea surface condition and situation, while their wind field becomes complex due to the terrains and structures, that is, their structure is small spatiotemporal scale. Their monitoring can be accomplished by a steep and high resolution data acquisition. The ordinal big lidars cannot be applied by downsizing their lidar systems. In this study, LED mini-lidar has been developed for the purpose of surface atmosphere monitoring. Installation of LED device for lidar light source causes the low utilization efficiency between transmitting light and receiving optical echo. On contrary, It brings use of wide wavelength selectivity and promises safety for human eye, and toughness for optical adjustment and surge electricity. With this mini-lidar, we aim to visualize and analyze the interaction between the ground surface and surface atmosphere and its dynamics.

In this report, we discuss installation of 265 nm LED device into the mini-lidar in theoretical approach. Its wavelength is in the solar blind Deep Ultra Violet (DUV) region, and it will successfully lead to the atmosphere measurement in daytime. DUV-light causes not only aerosol scattering, but also affects the molecular scattering, which is too big to ignore. By theoretical approach, we discuss the optimization of LED mini-lidar composition for the surface atmosphere with small spatiotemporal scale under the parameters of optical peak power, aperture of receiver's optics, and summation time.

2. Theoretical Approach

Theoretical analysis has been discussed to fix the 265nm mini-lidar specification. The ordinal lidar equation and signal-to-noise ratio (SNR) are used for this estimation[1]. The lidar optical parameters for those calculations are summarized in Table 1. DUV light region is a solar blind wavelength, and the lidar echo can be estimated without the influence of solar background light. The shorter wavelength generates the larger scattering cross-section of aerosols, while the atmospheric molecules cause large scattering, too. We estimate the scattering coefficients of the atmospheric aerosols and molecules as following equations[2].

$$\begin{aligned} \alpha_m(\lambda) &= \alpha_m(550) \cdot (\lambda/550)^{-4} \\ \alpha_p(\lambda) &= \alpha_p(550) \cdot (\lambda/550)^{-0.8} \end{aligned} \quad (1)$$

As a result, the backscattering coefficients are also estimated as $\beta_m(265) = \alpha_m(265)/50 = 7.662 \times 10^{-6} [1/m]$ and $\beta_p(265) = 4.094 \times 10^{-6} [1/m]$.

Table 1. Specification of LED mini-lidar on atmospheric echo estimation

Lidar optical parameters	
LED pulse power	$P_0 = 10 - 50 \text{ mW} = 0.1 - 0.5 \text{ nJ} / 10 \text{ ns}$
Optical efficiency	$K = 0.5$
Overlap distance	5 m (depends on alignment)
Aperture size	$D_i = 30 - 75 \text{ mm}$
Aperture area	$A_r = (D_i / 2.0)^2 \times \pi \text{ m}^2$
Number of summations	$M = 100,000$
Sampling time	$D_t = 10^{-9} \text{ s}$
Planck coefficient	$h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
LED center wavelength	$\lambda_0 = 265.0 \times 10^{-9} \text{ m}$
LED spectrum width	$\Delta\lambda = 10.0 \times 10^{-9} \text{ m}$
Optical frequency	$m_0 = 3.0 \times 10^8 / \lambda$
Quantum efficiency	$\eta = 0.2$
Pulse length	$2l_0 = 1.5 \text{ m}$
Noise factor	$\mu = 1$

Estimation and Experiment

Lidar echo has been estimated with the parameters of peak optical power and aperture of receiver as shown in Fig.1. The higher peak power and wider aperture have higher SNR in general. As the unique perspective is so small optical power can detect the atmospheric echo with enough SNR(Fig.1a). 10 mW peak power is 0.1 nJ at the pulse width of 10 ns. This 265nm LED mini-lidar can accomplish it with 1 second summation (1,000,000 shots at 1s), that is, it has potential to visualize the atmospheric activity with small spatiotemporal scale. Figure 1b shows the small aperture optical receiver is enough to get high SNR, too. It leads the lidar system to be quite compact with a handy size. We fabricated the concrete system with this estimation.

Figure 2 shows the daytime lidar echoes. It was measured with the concrete setup of the 265nm LED mini-lidar (See “265nm LED mini-lidar - Practical Approach-”). It is fabricated under the consideration of the above theoretical approach. DUV-LED device emits optical peak power of 25mW with pulse width of 10ns. In a sunny day, they have the same echo features, while only the backgrounds are changed due to the solar illumination that penetrate the OD6 blocking filter. It is confirmed that the background counts have linear relationship to the illumination. The fluctuation of echo counts has no large change under any solar illumination.

SNR of the atmospheric echo is estimated on the actual lidar echo counts with this fluctuated echo counts after subtracting the background lights. It is shown in Fig. 3. The experimental lidar echo with dots (1,400lx) is represented with SNR. In this figure, the theoretical curve of the peak optical power 10mW is drawn (orange curve). In the experiment, the actual peak power on the LED chip is 25mW, while the transmitting power after the beam collimation is 1/3 of the peak power. Furthermore, the larger beam divergence causes decrease of the optical coupling between the transmitting and receiving powers. The blue curve shows the above considerations from the 10mW theoretical curve. The experimental echo is well coincided with it.

3. Discussions

Low atmosphere and surface atmosphere are complex and steep dynamics due to the ground

/ sea surface and structure. The DUV-LED mini-lidar is suitable to capture their dynamics clearly. In human living area, the laser apparatus must be treated safely. This system satisfies that requirement.

DUV LED mini-lidar has potential for remote gas sensing[3]. Highly portable device gives the new seeds to match with various demands such as weather monitoring, air quality estimation, gas sensing and so on. We seek them with concrete demonstrations.

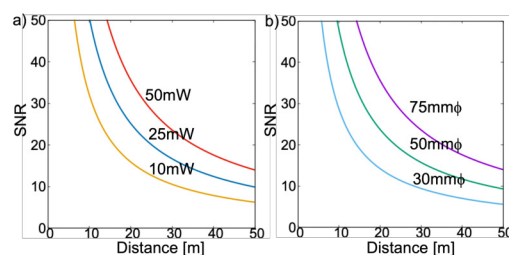


Figure 1 SNR Calculation Results a) Peak power variation b) Receiver aperture variation.

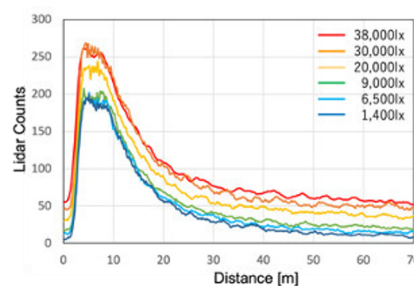


Figure 2 Daytime atmosphere measurements with 265nm LED mini-lidar. Summation : 10s.

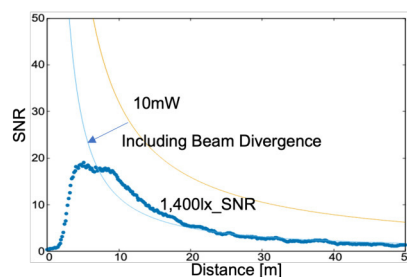


Figure 3 SNR estimation of lidar measurement echo with theoretical calculation.

4. References

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