Drone-Based Fluorescence Lidar for Agricultural Applications

Vasily N. Lednev[1,*], *Vladimir A.* Zavozin[1], *Mikhail Ya.* Grishin[1], *Daria V.* Grigorieva[2] and *Pavel A.* Sdvizhenskii[1]

[1]Prokhorov General Physics Institute of RAS, Moscow, Russia
[2]Belarusian State University, Minsk, Belarus

Abstract. We developed ultracompact fluorescence LiDAR for agricultural applications. To minimize the device, we used laser diode (wavelength 405 nm and power consumption 150 mW) and minispectrometer with wavelength range from 350 nm to 810 nm. We used single board computer to control LiDAR instrument. Small size (10×15×5 cm) and low weight (310 g) of the LiDAR make it possible to install it on a commercial unmanned aerial vehicle (UAV). Maize field have been sensed by LiDAR to distinguish healthy and plants under stress. Due the measurement we constructed field maps in different wavelengths of fluorescent radiation.

1 Introduction

It was early recognized that lasers are best sources for remote sensing of different objects [1]. Nowadays, LiDARs are installed on aerial vehicles such as planes, helicopters, drone etc. [2]. Such instruments can be helpful for navigation, mapping and searching. Past years many developments in unmanned aerial vehicles (UAVs) have been done. They are very helpful in places with any restrictions (administrative or physical). Aerial vehicles became widespread in agricultural sphere. One of the advantages of drone is accurate data collection ability from large spaces in a few minutes. Drones fly around the fields and create a map of crops properties [3,4]. Or they can search any defected plants in large areas which unreachable by humans without taking damage to crops. Also, drones are used to apply spray treatments that can be targeted to specific areas to maximize efficiency and save on chemical costs. But drones have limitations in payload. UAV can carry out weight from hundred grams up to hundred kilograms depending on the power of the engines and the size of the aircraft. This is the total weight without power supply. The battery can take up a significant proportion of all attachments. Therefore, it is important to develop compact devices with low power consumption for installing on small unmanned aerial vehicles [5,6].

In this report we present the development of ultracompact fluorescence LiDAR which was installed at commercial drone to monitor plants stress in agricultural fields. We provide recent results on maize field mapping by fluorescent LiDAR.

* Corresponding author: lednev@kapella.gpi.ru

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2 Experiment

2.1 Materials and Methods

We developed ultracompact fluorescence LiDAR for remote sensing of agricultural fields. Laser diode is the main part of our device. Laser diode has wavelength 405 nm and power consumption 150 mW. Other main component of LiDAR is a minispectrometer (STS-VIS by Ocean Optics). The spectrometer has wavelength range from 350 nm to 810 nm. The detector has 1024 pixels and one pixel with a size of 7.8×125 microns. We use an interference mirror (DMLP425, Thorlabs Inc.) to direct the laser beam to a remote object. Laser emission induced fluorescence of a remote object. We use fiber condenser to collect scattered radiation and direct it to the spectrometer. The minispectormeter has two removable slits with a size of 10 and 200 microns. Thus, the resolution can be changed from 1 nm for the slit of 10 microns to 12 nm for the slit of 200 microns. We used single board computer (Intel NUC) to control LiDAR instrument. We developed LiDAR's software in LabVIEW environment (National Instruments Inc.). The software can control the LiDAR in two modes. First mode is offline according to a given algorithm. Second mode is online control on Wi-Fi connection. Thus, the dimensions of the LiDAR are 10×15×5 cm (weight 310 g) and the dimensions of the computer are 11×11×3 cm (weight 600 g). The power consumption of the entire system (taking into account the control PC) is less 40 watts and the supply voltage is 12 V. Compactness, low weight and low power consumption are key factors for installing the instrument on commercial small drone. The LiDAR and computer can be easily separated so, good places at a flying platform can be suggested to keep the UAV center of mass. The developed ultra-compact LiDAR (the general view is shown in Fig. 1 (a)) was installed on a DJI Matrice 200 v2 quadcopter. The drone has max payload 1.45 kg with the batteries include.

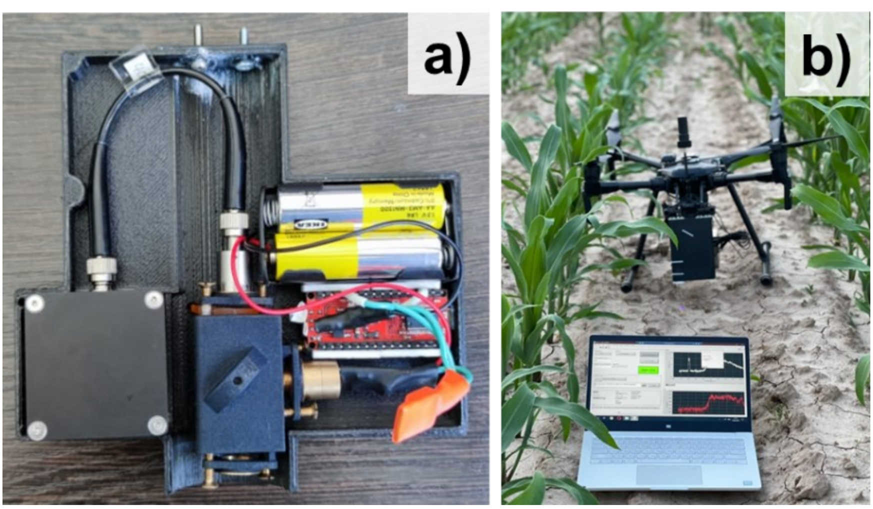

Fig. 1. A) Photograph of ultracompact fluorescence LiDAR without case cover. B) Photograph of unmanned aircraft vehicle with the LiDAR instrument installed and remote-control computer in maize field.

2.2 Location

We provide experiment on the maize field (Fig. 1 (b)) of the livestock farm "Zelenogradskoye" near the village of Semenovskoye (Pushkinsky district of the Moscow region). We installed an additional GPS tracker in the LiDAR to add coordinates to each recorded spectrum. A mapping of the field was carried out in area 3500 m^2. The results of the mapping of the maize field are presented below.

2.3 Results and Discussion

We present laser-induced fluorescence spectra of different part of maize plants on field a month before harvesting fig.2. As can be seen from Fig.2, two bands with centers at wavelengths of 680 nm and 740 nm can be observed in the laser-induced fluorescence spectrum.

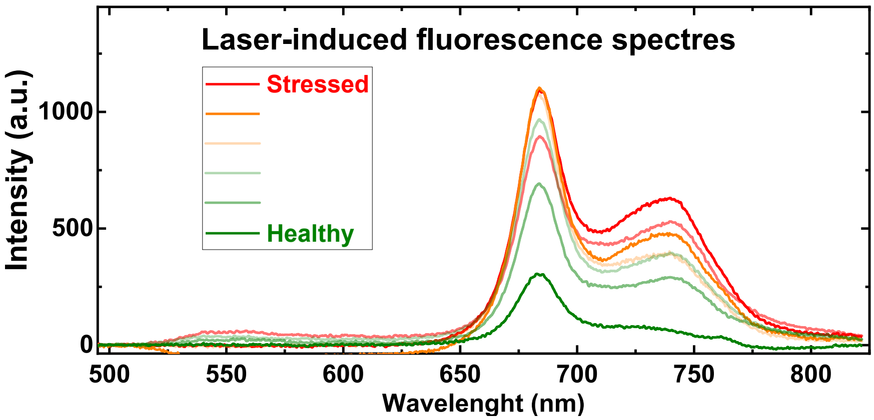

Fig. 2. Laser-induced fluorescence spectra of maize plant under stress (red line), and healthy maize plant (green line)

We have identified 3 signals for constructing field maps with different wavelengths of fluorescent radiation. First signal is a band integral centered at 680 nm (660-700 нм). Second signal is a band integral centered at 740 nm (700-760 nm). Third signal is a ratio of the first integral (center at 680 nm) to the second integral (center at 740 nm). The third signal is proportional to the concentration of chlorophyll in the sample [7, 8]. All maps of signals are presented on fig. 3.

Maps with a fluorescence signal centered at 680 nm and centered at 740 nm make it difficult to evaluate plant parameters. However, we clearly see an area with a decreased concentration of chlorophyll about two-fold lower compared to average level (fig. 3 (c)). This can be an indicator of stressed plants in this area of the field.

3 Conclusion

We developed ultracompact fluorescence LiDAR for remote sensing of agricultural fields. For minimization of device construction we used laser diode and minispectrometer. The dimensions of the development LiDAR instrument (10×15×5 cm^3,), low weight (310 g) and low power consumption (<40 watts) make it possible to utilize small aircraft platform. We provide measurement of the maize field using DJI Matrice 200 v2 quadcopter. We constructed maps of signal in different wavelengths of fluorescent radiation. We detected a 2-fold decrease of chlorophyll concentration compared to the average level in maize field.

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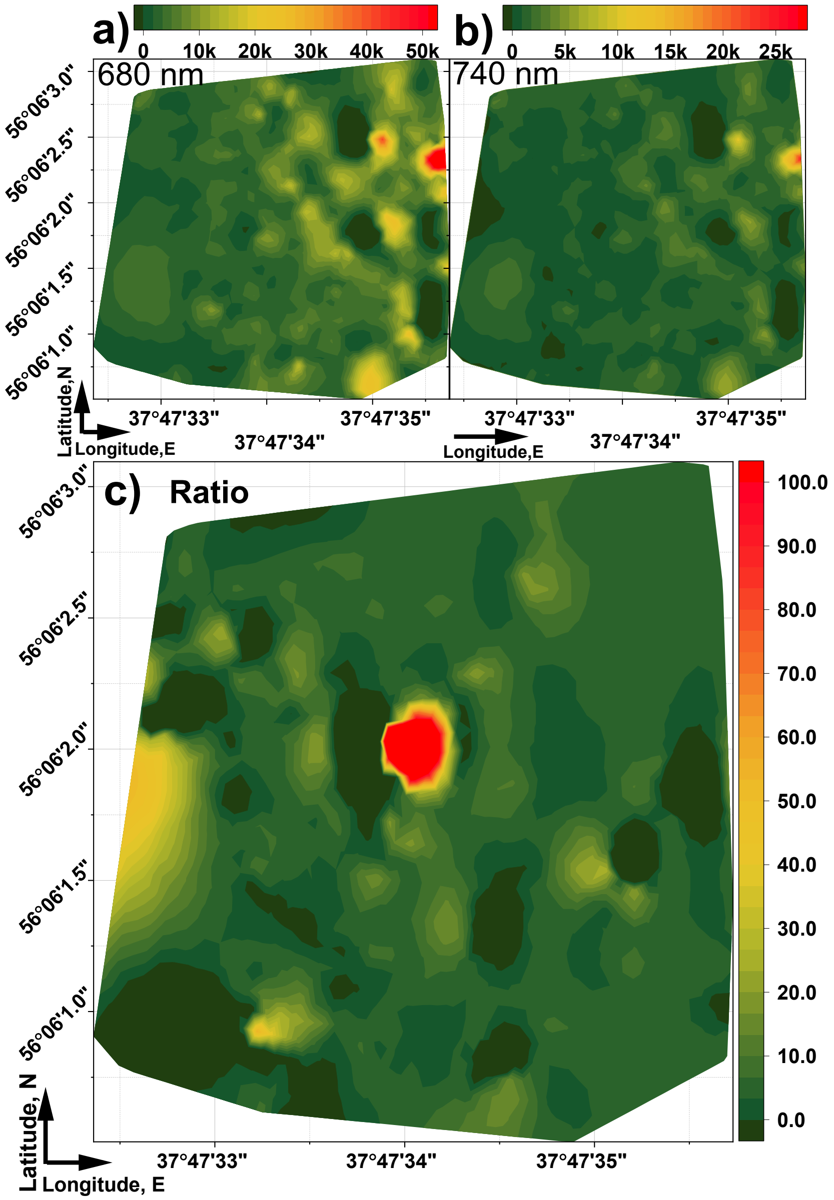

Fig. 3. Maps of fluorescence signals 680 nm (a), 740 nm (b) and ratios of integrals of fluorescence bands 680/740 nm (c) for the maize field.

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