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# DRONE-BASED FLUORESCENCE LIDAR SYSTEMS FOR VEGETATION AND MARINE ENVIRONMENT MONITORING

**Zheng Duan[1], Ying Li[1], Xun Wang[1], Jinlei Wang[1], Mikkel Brydegaard[2], Guangyu Zhao[1] and Sune Svanberg[1,2*]**

[1]*Center for Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal University, University City Campus, Guangzhou 510006, China*
[2]*Department of Physics, Lund University, SE 221 00 Lund, Sweden*
**Email: sune.svanberg@fysik.lth.se*

## ABSTRACT

We have developed two different types of drone-based fluorescence lidar systems for vegetation and marine environment monitoring, both based on violet CW diode lasers. An inelastic hyperspectral Scheimpflug lidar system was used for vegetation profiling combined with fluorescence spectral recordings. A light-weight fluorosensor set for fixed-height recordings was employed for monitoring of marine environments, featuring water Raman signals, algal chlorophyll and strong oil spill fluorescence.

## 1. INTRODUCTION

In the study of vegetation in agriculture and forestry, chlorophyll, responsible for photo-synthesis, is an essential indicator to reflect the growing conditions of vegetation. Chemical methods to monitor chlorophyll inside vegetation, e.g., extraction by acetone [1] are time-consuming and only available for laboratory quantification. Optical methods to monitor vegetation have merits of fast-response, non-invasive detection and high-sensitivity and are adapted to meet the need for large-scale monitoring and remote sensing. Laser-induced fluorescence spectroscopy (LIF) techniques are highly suitable for real-time, in-situ and non-invasive monitoring of vegetation status. When a short-wavelength excitation laser beam is impinging on vegetation, chlorophyll will efficiently absorb the radiation and re-emit fluorescence at longer wavelengths, which provides a finger-print characteristic of chlorophyll [2]. Combined with remote sensing techniques, the laser-induced fluorescence technique was applied to early remote monitoring studies of vegetation, e.g., spruce, maize and maple [3]; sugar beets [4] and corn [5]. In the past years we constructed a flexible mobile pulsed laser lidar system for environmental monitoring [6] and we reported fluorescence lidar applications for hybrid maize and hybrid rice [7,8]. However, while perfect for monitoring of, e.g., atmospheric atomic mercury [9], such a system is complex and expensive to operate when it comes to fluorescence monitoring, which is much less demanding [10]. The introduction of a compact inelastic hyperspectral Scheimpflug lidar system [11], makes it possible to realize simultaneous spatial and spectral information of distributed targets. Based on a commercial drone platform, we have developed a miniaturized hyperspectral lidar system for profiling the vegetation structure [12].

## 2. METHODOLOGY

### 2.1 Drone-based inelastic hyperspectral Scheimpflug lidar for vegetation monitoring

The setup used in our vegetation studies can be seen in Fig. 1. A commercial drone (DJI M600 Pro) with a maximum lifting capacity of 6.2 kg is utilized to carry the hyperspectral Scheimpflug lidar system. The excitation laser is a 1.5 W 445 nm Nichia diode laser with an adjustable-focus objective from Computar. A common industrial control computer is used for data capturing and storage. When the backscattered light from the objects is captured by the receiving telescope, the light, after beam redirection by a folding mirror, will pass through a slit with a width of 100 μm. A prism-grating-prism structure is used to disperse the light. After collimation by lenses, the light will be distributed on the imaging plane of an area CCD. A combination of the spatial and spectral information will be obtained in every frame.

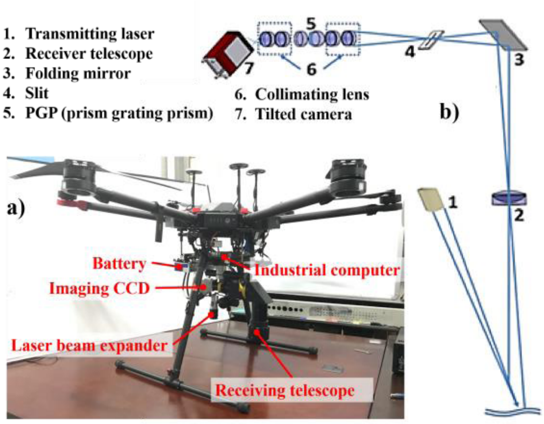


*Fig. 1. a) Drone-based inelastic hyperspectral Scheimpflug lidar for vegetation monitoring; b) Schematic of the lidar system, modified from [12].*

### 2.2 Drone-based fluorosensor for marine environment monitoring

The fluorosensor is equipped with a 1W, 412 nm diode laser (Xinrui, Model 412) and uses a compact spectrometer (USB4000 Ocean Optics) as the detector as seen in Fig. 2. A 425 nm long-pass filter (Edmund Optics #84-742) is used to cut off the excitation laser radiation. By tilting the laser, which is mounted non-coaxially next to the 50 mm diameter telescope with 200 mm focus, the measurement range is set to about 10 m. The laser beam is transmitted from the diode laser using a small collimator, and a telescope with a filter mounted after the objective is used to collect the fluorescence from the target. The laser can be directed at a proper angle to overlap with the telescope field-of-view as tuned according to the distance to the target. After the deflection from the mirror, the fluorescence is focused into the spectrometer and the data will be stored in an industrial control computer.

## 3. RESULTS

### 3.1 Vegetation monitoring

As a demonstration, we have monitored two trees behind our laboratory on the University City campus of South China Normal University with

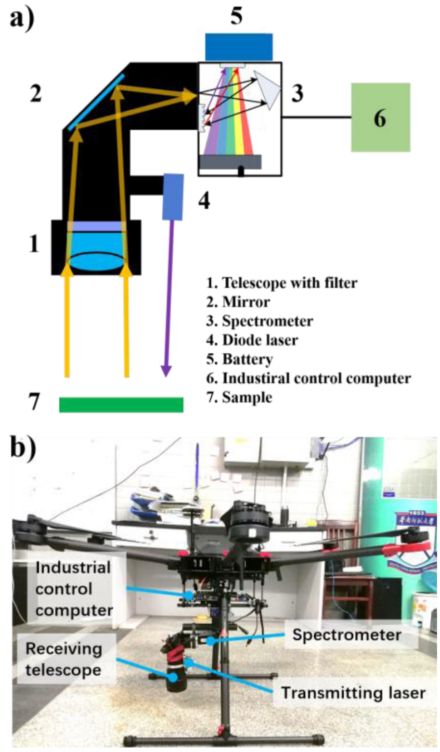


*Fig. 2. a) Schematic of the fluorosensor; b) Drone-based fluorosensor for marine environment monitoring.*

our inelastic hyperspectral Scheimpflug lidar based on a drone. As shown in Fig. 3, through integrating GPS (global positioning information) and INS (inertia navigation system) data with recorded frames, we can reconstruct these two trees with 3D point clouds with color coding of the spectral information. The fluorescence ratio between 690 nm and 730 nm was calculated as a relative measure of the concentration of chlorophyll in the vegetation. The yellow spots indicate the elastic signals without spectral information. Light from the road lamp constituting background noise could be suppressed by modulating the laser output.

### 3.2 Marine environment monitoring

The drone-based fluorosensor system is utilized to perform marine environment monitoring on the Zhujiang (Pearl) river, flowing with many branches through the city of Guangzhou. Two 90-cm-diameter floating containers were positioned on the surface of the river as artificial targets. One was filled with 1 litre of pure engine oil, resulting in layer thickness of typically 1-2 mm, and the other one was filled with 10 litres of a dilute solution of Rhodamine 610 dye with the

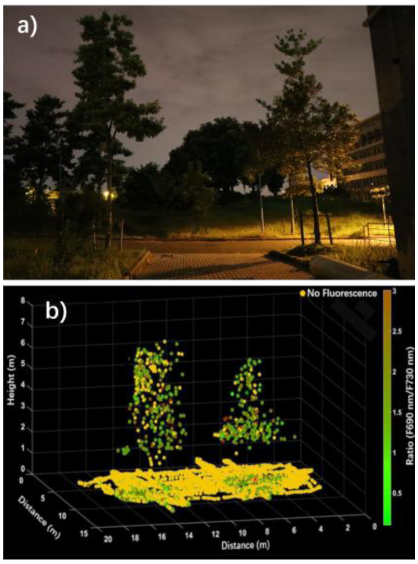


*Fig. 3. a) Photo of two trees as targets; b) Point cloud figure of two trees with spectral information captured by the drone lidar; Color map coding corresponding to the ratio of chlorophyll fluorescence (F690/F730) is employed; modified from [12].*

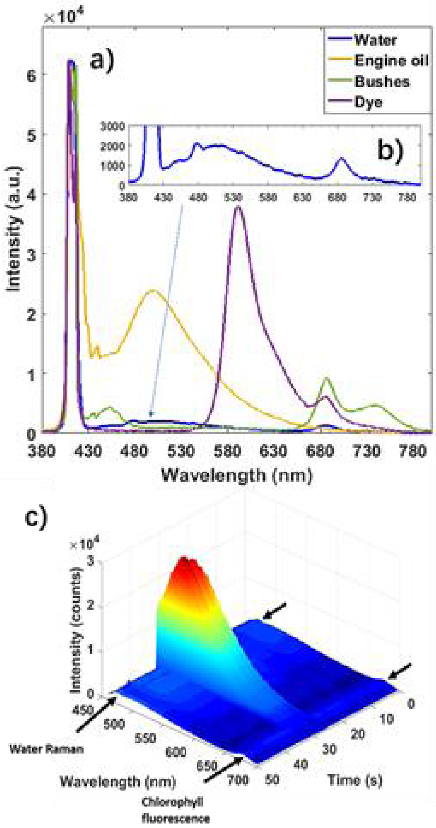


*Fig. 4. a) Spectra captured by the drone-based flurosensor over the Zhujiang river; b) Zoom-in spectrum of natural Zhujiang river; c) Result of a linear scan of an oil-filled floating container on Zhujiang river. The exposure time of the spectrometer was set to 0.5 s; modified from [17].*

concentration of 0.03g/l, resulting in a 1-2 cm layer thickness. The dye is dissolved in natural Zhujiang river water. With the drone scanning along a setup flight route covering the artificial targets, the measurements are illustrated in Fig. 4 a) and b). Four typical spectra recorded by the flurosensor are presented. The characteristic fluorescence peak of oil at 500 nm and dye fluorescence peak at 580 nm can be observed. Vegetation on the riverbank was also covered, and the strong chlorophyll characteristic peaks at 685 nm and 745 nm are recorded. In the zoom-in spectrum of the natural Zhujiang water, strong dissolved organic matter (DOM) fluorescence and algal chlorophyll signals are shown, as well as the water Raman peak at 480 nm. A linear scan of the oil-filled container with a continuous recording of 50 s is presented in Fig. 4 c). High sensitivity of the fluorosensor towards oil spills can be noticed, as contrasted to the background water Raman, algal chlorophyll and DOM signals.

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