Combined multispectral laser scanning and coherent 3D LiDAR imaging for remote sensing of crops

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2D multispectral differential absorption and range measurements demonstrate the evaluation of the moisture content spatial distribution and 3D shape reconstruction of an apple. The combined absorption-3D imaging meausrements proposed approach enables compact crops evaluation systems.
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Early indication of plant health status using remote sensing through spectral characteristics of plant can help fight the risk of diseases. Remote sensing using passive techniques as, e.g. hyperspectral cameras relying on solar radiation are highly affected by atmospheric illumination and provide low signal-to-noise ratio (SNR). The more effective and performing active remote sensing is implemented using single/multi-wavelengths [1,2] or hyperspectral imaging exploiting supercontinuum (SC) lasers [3]. The capability of implementing remote 3D reconstruction, i.e. object identification, in conjunction with multi-spectral analysis allows to evaluate the crop in terms of yield estimation and also indicates plant stress by monitoring the shape of plant. Nevertheless, typical single/multi- wavelength lidar systems do not provide 3D imaging functionality in-conjunction with absorption spectrum. Only a recent implementation of hyperspectral lidar using SC laser can provide 3D image reconstruction of a plant along with biophysical properties in multiple spectrums over a spectral range of 480-2200nm [3]. Commonly used active illumination methods for these techniques exploit high peak power pulsed laser. Here we present a lidar system that combines multispectral (dual-wavelength) laser scanning for monitoring the moisture content and 3D imaging functionality by utilizing frequency-modulated continuous wave (CW) beams with coherent detection. The use of dual-wavelength allows to visualize the feature of interest in a differential image e.g. moisture content that absorbs strongly at a specific wavelength. Moreover, the use of coherent detection avoids expensive single-photon detectors, making the scheme compatible with photonic integration.

The setup of the dual-wavelength laser scanner combined with 3D LiDAR is shown in Fig.1. The wavelengths λ_1=1450nm allows for evaluating the water content and the wavelength λ_2=1550nm works as reference channel to perform the differential absorption measurements. The two collinear wavelengths are used to remotely scan in 2D using dual-axis galvanometer system. For the 3D imaging, a carrier suppressed dual-side band (40MHz) modulated signal at 1550nm is used in conjunction with coherent detection to enhance the system sensitivity. As a proof of concept, an apple with a portion of fungal decomposition (rotting) was scanned with a resolution of 30x30 pixels using the combined dual-wavelength scanner. The differential off target echo (shown in Fig. 2(a.4)) clearly demarcates the high and low water saturated regions. Moreover, the 2D absorption scan has clearly revealed the decomposed area of the target. Furthermore, a partial 3D image of the apple from the side and front view is obtained (Fig. 2(b.2) & (b.4)). The presented results reveal the possibility of realization of a simplified and efficient remote sensing system suitable for monitoring the biophysical properties and yield estimation of plants/vegetation. The proposed scheme can be compactified using emerging photonic integrated circuit technologies, thereby realizing low power, small-footprint and smart multispectral scanner for crop monitoring.

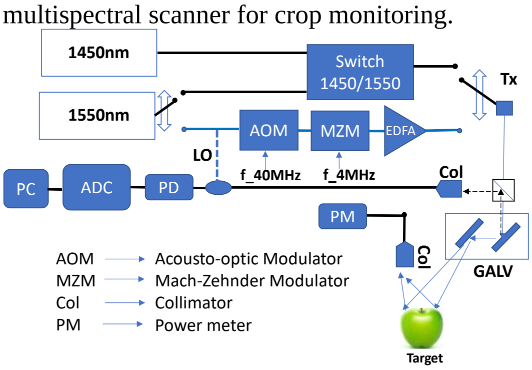

Fig. 1 Experimental setup.

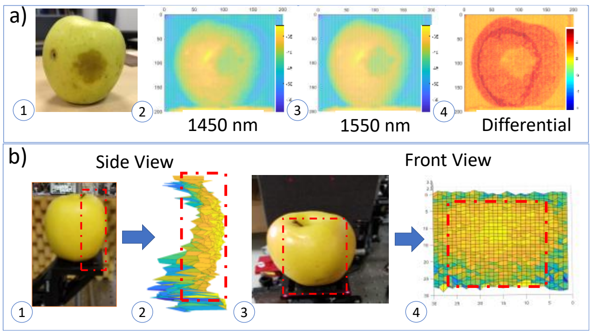

Fig. 2(a.1) Scanned Apple (a.2) Image at 1450nm channel (a.3) Image at 1550nm channel (a.4) Differential image. (b.1) Side view of scanned apple (b.2) 3D image (side view) (b.3) Front view of scanned apple (b.4) 3D image (front view).

References

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