# Low-cost and Lightweight Hyperspectral Lidar for Mapping Vegetation Fluorescence

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Lidar vegetation profiling has recently gained interest as a complement to the more established hyperspectral imaging. Whereas hyperspectral imaging can identify the molecular composition at the top of the canopy, vegetation lidar can quantify the height distribution over ground. The height distribution has impacts on the associated species composition and diversity. Attempts to increase the specificity of vegetation lidars have been explored by increasing the number of spectral bands or by fusing lidar data with hyperspectral imagers. However, the fine structure of leaves and branches makes it challenging to synchronize and overlap bands or instruments in time and space. In addition, experiments with elastic super-continuous hyperspectral lidars have shown that signals become unstable because of the random orientation of leaves when resolution reach these features.

To increase specificity while retaining a high spatial resolution, we have developed active remote sensing concepts and designed an inelastic hyperspectral lidar for vegetation autofluorescence. The instrument is based on a violet 1W, 402 nm laser diode. The laser transect is imaged through a slit with a double Scheimpflug configuration and spectrally dispersed by a grating, providing both ranging and spectral resolution. Stacking exposures then provide an intensity data cube with the axes of range, wavelength, and time, thus constituting hyperspectral full-waveform lidar echoes over time. The operation range is designed from 5 to 100 m, and it covers 70 effective spectral channels from 400 to 800 nm; the maximum framerate is at 120 Hz. We employ a laser modulated lock-in detection scheme whereby fluorescence signals can be retrieved during the daytime. The instrument was partly constructed with reinforced filament 3D printing. The bill of materials was ~US$ 5000 and the system weighs ~3 kg without a tripod.

We report initial instrument performance assessment and results from experiments conducted at the Lund University Field Station Stensoffa, situated in southern Sweden. The lidar was mounted on a tripod, and several tree species were scanned from a distance of 5-100 m during the day and night. Tree species were identified in the field. We demonstrate species contrast by distinct fluorescence signatures. We used an automated 2D scanning pattern programmed for the lidar, providing a 3D-spatial hyperspectral image of the vegetation autofluorescence from a single point of observation. This method is promising for low-cost and lightweight fluorescence lidars and paves the way for merging the capabilities of vegetation lidar and hyperspectral technology, improving remote tree species classification.