Laser sensing of arboreous plant fluorescence in western Siberia

Oleg Romanovskii, Gennadii Matvienko, Anatolii Grishin, and Olga Kharchenko

A lidar system is used to observe tree species and their chlorophyll content, laying the groundwork for a remote approach to forest ecosystem monitoring.

The advent of high-power lasers operating in the near-UV and visible spectral regions has fostered extension of spectroscopic analysis methods to the domain of remote sensing. To examine plants in this context, both spectral and temporal dependences of laser-induced fluorescence (LIF) can be used.\textsuperscript{1,2} Light detection and ranging (lidar) measurements of the fluorescence of arboreal plants growing in natural habitat were performed by the authors.\textsuperscript{3–6}

This type of research has not previously been undertaken in the Siberian environment. Objectives of our research include qualitative analysis of organic LIF, plant species identification, analysis of fluorescence variations caused by environmental changes, and quantification and identification of chlorophyll content in arboreal plants. The objects of investigation were typical Siberian trees: birch (\emph{Betula pendula} Roth.), aspen (\emph{Populus tremula} L.), common pine (\emph{Pinus silvestris} L.), and cedar pine (\emph{Pinus sibirica}). These species are essential components in the plant communities of mixed and coniferous forests.

Initially, experimental research was carried out using a lidar system with two receiving telescopes, one tuned to detect fluorescence signals at 685nm and the other operating at a wavelength of 532nm.\textsuperscript{7} To enhance performance, the lidar was upgraded to give fuller spectra of chlorophyll fluorescence. The primary advantage of the improved lidar model was detection of the LIF signals not only in the region of 685nm, but also around the second peak of chlorophyll fluorescence at 740nm (see Figure 1).\textsuperscript{8}

Measurements were taken continuously from March to November, twice a week, in the evening and during the night (see Figure 2).\textsuperscript{9} During the observation period, fluorescence characteristics were species-dependent, owing to differences in the fluorescence intensity of different plant species that are caused by varying content of fluorscing pigments (i.e., chlorophyll), as well as to differences in how absorbed energy is distributed between the chlorophyll-protein complexes and reaction centers of the two photosystems. The LIF of birch exceeded that of the other species except during the fall, when fluorescence of broad-leaf trees weakens compared with that of conifers due to foliage loss. The LIF of aspen took the intermediate position between the LIFs of birch and pine.

To determine chlorophyll content in the needles and leaves of arboreal plants, we performed a series of experiments with samples of pine, aspen, and birch (see Figure 3). To minimize uncertainties arising because of inhomogeneous quality of leaves

\begin{figure}
\centering
\includegraphics[width=\textwidth]{functional_scheme.png}
\caption{Functional scheme of the fluorescence lidar (light detection and ranging) system for vegetation study. The laser sends a pulse at a wavelength of 532nm toward the target object, causing the latter to fluoresce. Part of the radiation is caught by the receiving telescope and transmitted to the spectrophotometer. The radiation intensity is measured at all three wavelengths: 685, 740, and 532nm. (The first two wavelengths are determined by the fluorescence of the chlorophyll \emph{a}. The third is needed to normalize the received laser-induced fluorescence radiation.) From the output of the spectrophotometer, the radiation is transmitted to the photomultipliers (1, 2, 3) used as photodetectors. Then, three electric signals are directed to the analog-to-digital converter (ADC), from where it continues to a computer, in which accumulated signals are preprocessed and recorded.}
\end{figure}
in the crown and generally over the stand, we selected samples from the same story, from the middle crown of the same species. The samples were growing 70m away from the fluorescence lidar and thus were laser-irradiated from this distance.

To assess the accuracy of our fluorescence-based method, we also determined the chlorophyll content in the needles and leaves of these samples by the traditional biochemical method. Comparison of the direct and lidar chlorophyll measurements revealed a distinct relationship between them (see Figure 4). The qualitative behavior, dynamics, and variability ranges of the chlorophyll content coincide for all the tree species involved in the experiment. The results of spectrophotometer measurements confirm the reliability of the LIF method. Based on analysis of the biochemical and lidar measurements, we have calibrated the lidar to determine the chlorophyll concentration in arboreous plants by the ratio of the LIF signals, enabling direct measurements of chlorophyll via lidar for quantitative evaluation.

The LIF technique has promise for many applications involving photosynthesizing organisms, such as biomass evaluation, plant cover identification, and plant stress diagnostics.

### Author Information

Oleg Romanovskii, Gennadii Matvienko, Anatolii Grishin, and Olga Kharchenko
Institute of Atmospheric Optics
Russian Academy of Science, Siberian Branch
Tomsk, Russia

### References


Continued on next page

