SOUNDING OF UNDERLYING SURFACE USING A FLUORESCENT LIDAR

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A fluorescent lidar has been described. Its absolute sensitivity has been estimated. Results obtained with the lidar placed onboard a helicopter–laboratory are presented.

In the last few years, there has been a rapid progress in active methods of laser sounding to collect data on the Earth's surface and the atmosphere measured from space and from airborne platforms.

Employment of short–wavelength lasers for sounding was an important step forward in this direction since they offer possibility of harnessing fluorescence induced by laser radiation. This leads to the development of a new laser system for remote sensing called laser fluorimeter.

Such a laser fluorimeter (its external view is shown in Fig. 1) was developed at the Scientific–Production Association "State Institute of Applied Optics" in collaboration with the Special Design Office of the Estonian Academy of Sciences. Figure 2 shows a layout of the fluorimeter.

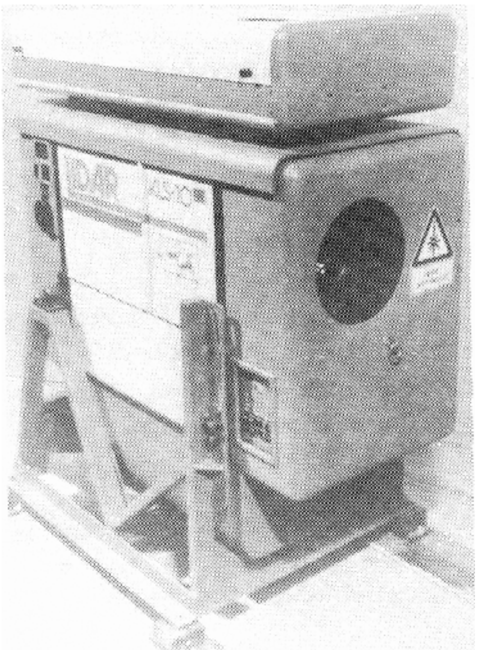

FIG. 1. External view of laser spectrometer for remote sensing.

An excimer XeCl laser ($\lambda = 308$ nm) developed at the Special Design Office of the Estonian Academy of Sciences is a source of the UV radiation. This laser operates with electrode separation of 20 mm and a working gas mixture ratio HCl:Xe:Ne = 0.1:1.0:98.9 at a gauge pressure of 3 atm. The angular beam divergence is 5 mrad. This laser can be used for dye laser pumping and as a sounding source for sounding range of the order of several tens of meters. Pulse energy reaches 140 mJ. Due to its vibration resistance and hermetic construction, laser source is unaffected by the environment and is capable of outdoor operation from different means of transport.

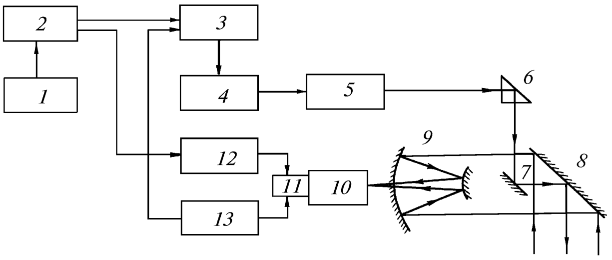

FIG. 2. Lidar layout: clock pulse generator (1), delay generator (2), excimer laser control unit (3), excimer laser (4), dye laser (5), rotating prism (6), rotating mirrors (7 and 8), telescope (9), polychromator (10), multichannel receiver of radiation (11), generator of gate pulses (12), and computer (13).

A dye laser "Estla," specially developed for portable lidar in Tartu, serves as a tunable sounding radiation source and includes an oscillator, preamplifier, output power amplifier, and frequency doubler. Driving generator of the laser consists of a diffraction grating, semitransparent quartz plate, multiprism beam expander, and a cell with flowing dye and transverse pumping. Dye replacement is made without misalignment of a cavity. The pumping radiation is focused into the cell with cylindrical lenses. Tuning to a given wavelength is carried out both manually and using a stepping motor with wavelength indication given by a mechanical counter. Tuning range extends from 360 to 760 nm without frequency doubling and expands into the UV up to 260 nm with frequency doubling. Pump conversion efficiency to the visible falls within the range from 0.08 to 0.145 depending on the dye type. Output beam divergence is better than 0.5 mrad.

Output sounding beam is directed along the receiver optical axis by means of an adjustable prism and a mirror. Tilt of the rotating mirror determines the angle of incidence of the sounding radiation on the surface being studied. Lidar return signal is recorded by a spectral optical unit that includes a telescope and polychromator. A vertically symmetric scheme with a set of changeable diffraction gratings (300 and 600 rulings/mm) is used in the polychromator. A corresponding receiver range of wavelengths is adjusted by rotation of the grating with wavelength indication given by the mechanical counter. Specifications of the spectral optical unit are given below.

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Spectral optical unit

Spectral range, nm	250–850
Receiving aperture, mm	180
Relative aperture	1:4.2
Linear resolution within 20 mm, nm	0.15
Recorder	
Spectral range, nm	380–820
Number of resolved pixels	512
Pixel size, μm	26×500
Dynamic range	10^3

A special chamber including a brightness amplifier, electron–optical image converter (EC–10 (EOIC)), and an FPPZ–7 multichannel photodetector is used as a receiver of radiation.

After polychromator, the signal spectrum is projected on the EOIC photocathode. The intensified image from a converter screen is transmitted through an optical fiber washer to a photosensitive surface of a multielement detector.

Synchronization of receiving and transmitting systems is provided by an external generator of clock pulses. A delay generator generates two time–delayed synchronizing pulses for actuating of the excimer laser and generator of gate pulses of the chamber. Gate pulse duration determines spacial lidar resolution, the delay specifies the sounding range, and the pulse repetition frequency determines lidar resolution on the surface. The pulse repetition frequency is varied from 1 to 5 Hz. The appropriate level of the signal–to–noise ratio is provided by integrating of the lidar return signal spectra depending on lidar operation mode and output radiation wavelength. An IBM PC/AT/286 computer provides the control over operation modes of radiation sources and receiving and signal processing systems.

In order to estimate quantitatively the sounding range and threshold characteristics of the lidar in remote sensing of fluorescent objects, we carried out direct measurements of lidar sensitivity.

The energetic brightness sensitivity of the lidar was measured with extended calibration source formed by a standard plate with known spectral transmittance in the whole spectral region of lidar sensitivity that was illuminated by a tungsten strip lamp with known spectral energetic brightness of its heated body.

The threshold brightness value $L_{\rm th}$ measured by the lidar for signal–to–noise ratio being equal to 3 within a gate pulse voltage of 0.9 kV was $L_{\rm th} = 10^{-3}$ W/(sr$\cdot$m$^2\cdot\mu$m) at $\lambda = 615$ nm. The sensitivity obtained is good as compared to that of radiometers operating in the visible.

This sensitivity enables us to obtain quantitative estimations of the content of fluorescent components on investigated surfaces without calibration of fluorescence signal by the method of internal reference[1,2] taking into account the lidar equation for fluorescent object (see, for instance, Ref. 3).

A MI–8 MTV helicopter–laboratory was created to solve ecological problems in Tatarstan. A number of devices were mounted onboard the helicopter, including fluorescent lidar described above, to solve specific ecological problems The underlying surface was irradiated by a laser beam transmitted vertically downwards through a special hatch in a helicopter floor.

Spatial scanning of the underlying surface was provided by helicopter motion. The flight altitude varied from 50 to 300 m. Integrated investigations of water surface of the Volga and Kazanka rivers, Lake Kaban, as well as vegetation near Kazan' were performed with this helicopter–laboratory.

Figure 3 shows the spectra of the underlying surface obtained with fluorescent lidar placed onboard the helicopter–laboratory. As is seen from Fig. 3, the sensitivity of the device is sufficient to obtain useful information for solving ecological problems. All measurements were carried out in the daytime; nevertheless, solar illumination was no barrier to recording of these spectra.

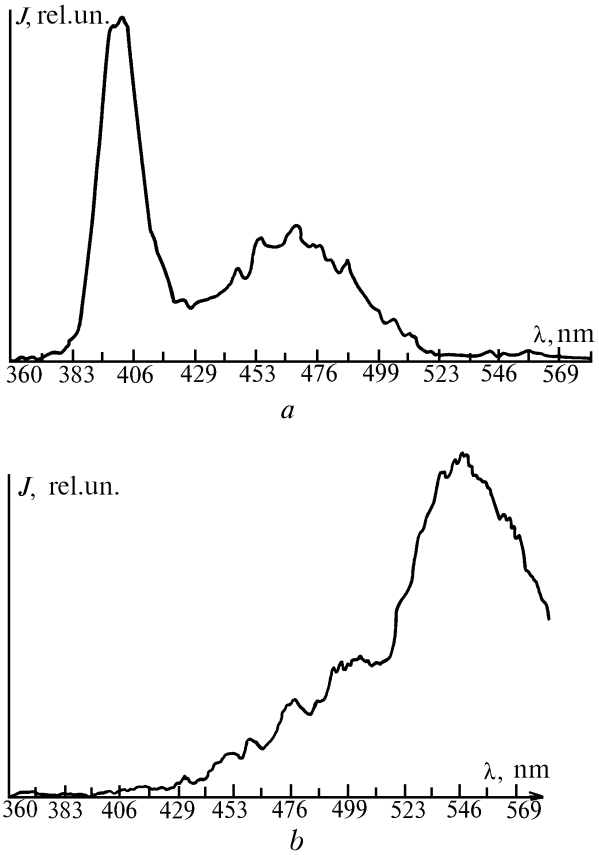

FIG. 3. pectra of underlying surface observed from an altitude of 100 m *at* $\lambda = 308$ nm: *a) the Volga near Bauman region and b) Lake Srednii Kaban near the Thermal Power Station.*

Thus, from the known lidar sensitivity one can derive the quantitative characteristics of fluorescent components from the recorded spectra.

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