Dual-wavelength cw CO_2-laser system for a parametric autodyne lidar

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The new version of dual wavelength cw CO_2 laser for autodyne DIAL-lidar is considered.

It is known[1–4] that a laser, operating in the autodyne generation mode, is a highly sensitive detector of radiation. This property can be profitably used in the differential absorption lidar method in monitoring of the atmospheric gas components of different origin at their extremely low concentrations. The use of this method assumes employment of a laser system simultaneously (or at close moments in time) generating at two wavelengths, one of which is in the range of the absorption line center and the other one in the line wing; at the first wavelength the absorption is maximum, at the second wavelength the absorption is minimum.

The possibilities of using the differential absorption method in a parametric autodyne CO_2 laser to perform gas analysis of the atmosphere have earlier been investigated experimentally and theoretically.[5–9] The calculations have shown that a wide range of gases (~20 species), whose absorption bands are in the region of CO_2-laser generation, 9 to 11 μm, for horizontal paths can be detected at the concentration level from 0.5 to 20 ppbV.

The dual-frequency laser operation was realized in Refs. 5 and 6 with the use of one laser tube that enabled us at the first sight to make a gas analyzer cheaper, as compared with the use of two lasers, and, probably, more compact. However, in such a laser it is impossible technically to obtain the generation in different channels at the lines of CO_2 radiation that are close in the emission spectrum. The attainment of radiation frequency stability is also problematic because the cross mechanical modulation of channels results in a failure of the stabilization system regime. If the channels generate simultaneously, the competition of amplification in the lines takes place again resulting in unstable generation. The use of two separate discharge tubes makes it possible, on the one hand, to provide independent frequency retuning and stabilization in the generation channels, and, on the other hand, to use the generation power completely that, as a result, should lead to an increase in the measurement sensitivity.

We have developed the laser system (Fig. 1) based on two CO_2 lasers operating in a continuous wave single-mode regime and tunable over the generation lines in the range from 940 to 1087 cm^{-1}.

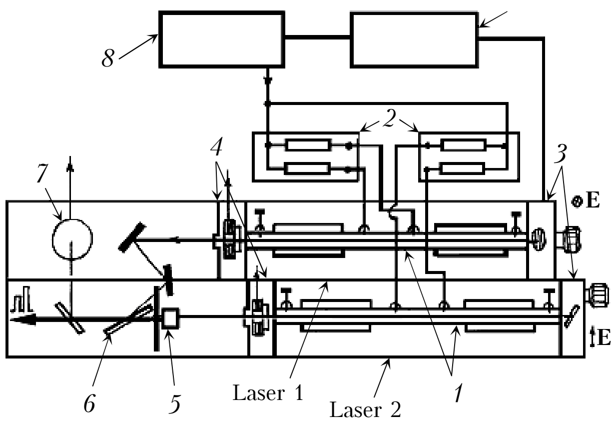

Fig. 1. Optical layout of the laser: *1* discharge BeO tubes cooled by water; *2* blocks of ballast resistors; *3* flanges with diffraction gratings; *4* flanges with output mirrors on piezocorrectors; *5* chopper; *6* Germanium plate at the Brewster angle; *7* photoresistor of GeAu; *8* power supply of the discharge gaps; *9* block of laser control.

A basis for the construction is the equipment mounted based on six Invar rods. Discharge tubes are made from BeO ceramics and have two discharge intervals of 176 mm length. Basic specifications of the laser are given below.

Mode of generation	cw single-mode, single frequency
Tuning range, cm^{-1}	940–1087
Discharge current, mA	7
Voltage, kV	5

Output power at the center of the amplification contour (lines 9*P*(16)–9*P*(24)), W	≥ 2
Diameter of the output beam, mm	4
Frequency jitter of the line, MHz/s	≤ 0.5
Control voltage, V	0–250
Frequency of the cavity length modulation, Hz	≤ 300
Amplitude of the cavity length modulation, μm	7.5
Piezoceramics sensitivity, μm /V	0.03
Gas composition	CO_2:N_2:He = 1:1:4
Optimal pressure of the gas mixture, Torr	≈ 40
Dimensions of the optical head, mm	1250×400×250

The cavity of each laser is formed by a diffraction grating (150 grooves/mm) and a concave mirror located close to the ends of the discharge tubes on the positioning heads. Diffraction gratings for tuning to a chosen line are turned by hand using microscrews (the calibration chart is given in Fig. 2). The mirrors are mounted to the heads through piezocorrectors KP-1, providing scanning of the cavity length by distances more than 15 μm.

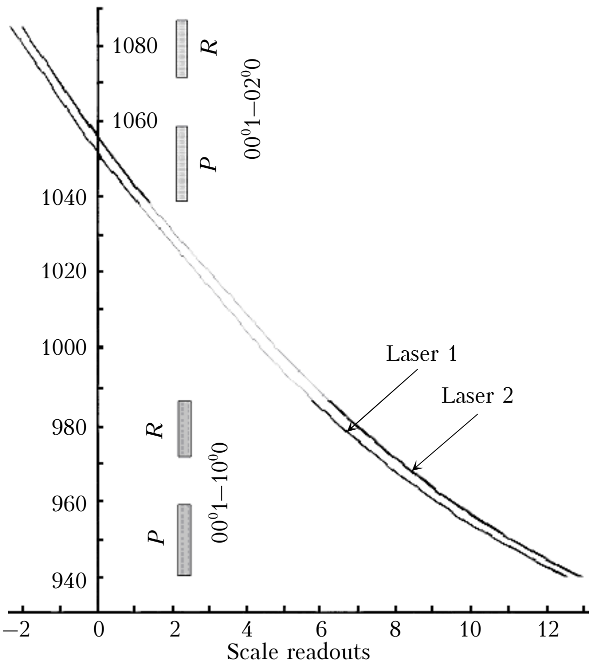

Fig. 2. Calibration diagram for tuning laser radiation wavelength.

Piezocorrectors are used both for wavelength scanning (that is necessary according to the principle of operation of autodyne lidar) and for optogalvanic stabilization of the laser frequency at the lines chosen.

The output laser beams have linear, mutually perpendicular polarization. By means of two mirrors the laser beams intersect on a germanium plate placed at the Brewster angle to the axis of one of the beams (before bringing together, both beams are transmitted through a modulator providing alternate beam interruption). The plate reflects more than 80% of the beam power of *s*-polarization in the required direction. This version of the beam mixing provides for a broadband operation necessary for the operation throughout the entire spectrum of CO_2-laser emission and that is difficult to do by means of multilayer light divider. As a result the laser system generates pulses at a repetition frequency of 100 Hz at two different wavelengths that makes it suitable for use in the autodyne lidar.

The system has a built-in cooled photodetector based on GeAu to record the emission power of both lasers.

Acknowledgments

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