

# EXPERIMENTAL SETUP FOR INVESTIGATING INTO THE PROPAGATION EFFECTS OF BIMODAL LASER RADIATION IN THE ATMOSPHERE

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*Received March 5, 1994*

*The experimental setup for investigating the effects of scattering of bimodal radiation propagating in the atmosphere is described. The differential scheme realized as two optical branches, reference and operating ones, similar to interferometric measurements, is used as a basis of the concept of measurements. However, in contrast to the interferometry, the amplitudes of light waves but not the phases are compared. The measurements are accurate to not worse than 0.5% of the values of detected signals.*

## INTRODUCTION

The bimodal laser field interaction with atmospheric gases was experimentally and theoretically investigated in Refs. 1–6. The results of these works gave new opportunities for standard applications of atmospheric spectroscopy, in particular, in atmospheric sounding using methods of active Raman spectroscopy.<sup>7</sup>

It turned out, however, that to understand the dynamics of observed processes one needs for an experimental setup providing a possibility of modeling the atmosphere in a more wide range of parameters (composition, density, etc.) and higher measurement accuracy than previously achieved. In this paper we present a description and results of testing a new setup, that, in our opinion, meets these requirements. Its salient features are the following.

It is known that tunable lasers, employed in most of bimodal radiation experiments, provide the difference frequency range from units to several thousands reciprocal centimeters.<sup>7</sup> Therefore their application to the problems of atmospheric optics is limited because of a strong divergence of the beams of bimodal pumping. In the presented setup this limitation is mostly removed because it implies the difference frequency range from the thousandths to several units reciprocal centimeters, i.e. less by a factor of  $10^3$ .

As a basis of the concept of measurements we use the differential scheme realized as two optical branches, reference and operating ones, similar to the interferometric measurements with the only distinction that we compare amplitudes of light waves but not the phases.

Consider now in more detail the setup's functional block-diagram and performance of its principal blocks.

## FUNCTIONAL BLOCK-DIAGRAM OF THE SETUP

The operation of the setup (Fig. 1) is as follows. The bimodal radiation from a laser 1 is divided into two beams with a beam splitting mirror 2. The first beam passes through a test chamber 4 and through the input window 5 of a modulator, and afterwards the lens 6 directs it to the entrance slit of a spectral device 7. The second, reference beam, with the help of semitransparent 2 and rotating 3 mirrors passes appointed distance in the air at room temperature and pressure, and then it is also directed to the entrance slit. The light shutter 5, rotating with appointed frequency, transmits to the entrance slit in consecutive order light beams from operating and reference branches. After passing the mirror lens

and dispersive unit of a spectral device the signals come to waveguides 8 whose ends are placed in a focal plane of a chamber lens of the device. The waveguides 8 transmit the signals from the spectral regions under study to an assembly of photoelectric multipliers 9, which converts them into electric signals processed then with the recorder unit 10. Here the signals are stored and compared by amplitudes.

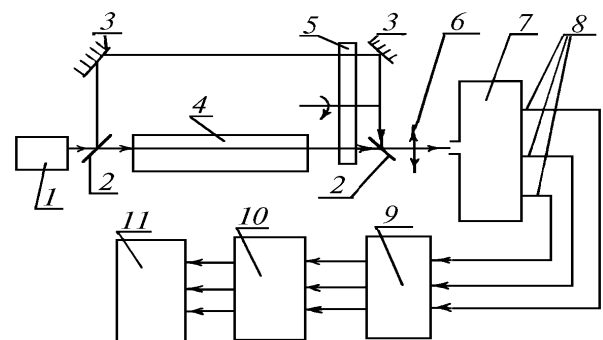


FIG. 1. Block-diagram of the setup for investigating into the propagation effects of bimodal radiation in the atmosphere: laser (1), semitransparent mirrors (2), rotating mirrors (3), vacuum chamber (4), light shutter (5), receiving lens (6), spectral device (7), optical waveguides (8), PMT assembly (9), processing unit (10), and oscilloscope (11).

The difference signal is amplified and displayed on an oscilloscope 11. By changing density or composition of a gas in the test chamber, one can obtain after signal processing the dependence of scattering cross section of the process under study (i.e. intensity of scattered light) on the parameters of scattering medium or on the spectral and energy characteristics of bimodal laser radiation.

## BIMODAL LIGHT SOURCE AND SPECTRAL DEVICE

As was mentioned above, tunable lasers<sup>7</sup> are mostly employed in the bimodal radiation experiments. Their use provides for the difference frequencies from units to thousands of reciprocal centimeters. We used difference frequencies from a few thousandths to units of reciprocal centimeters which are less by a factor of  $10^3$ . Therefore, to produce such frequencies we used different methods of selecting the

longitudinal modes in the solid-state and gas lasers, e.g. by installing within the resonator a Fabry-Perot etalon, diaphragm for suppressing higher transverse modes, etc.<sup>8,9</sup>

For spectrum analyzer we used a grating spectrograph DFS-452 with the changeable diffraction gratings of 600 and 1 200 grooves/mm, input  $f/D$  ratio of the device being 20:1. The inverse linear dispersion of the spectrograph is 0.8...0.63 nm/mm in the first order and 0.5...0.2 nm/mm in the second order of diffraction. The spectra were recorded either with a photographic plate of 9 by 24 cm<sup>2</sup> size or with an array of optical waveguides placed in the focal plane and connected with PMTs. The spectral region of high recording quality covers 100 mm in length (50 mm at both sides from the holder center), therefore the sequential spectrum scanning is used to provide high quality of spectrum recording.

The spectrograph's light condenser includes three condensers (only one could also be used) and a condenser holder. We used a single condenser of K8 glass.

### TEST CHAMBER AND VACUUM EQUIPMENT

The test chamber is a cylinder 170 cm long of quartz tube 5 cm in diameter and windows of K8 glass. The chamber is mounted on a vacuum unit with two K8-glass tube branches attached to the ends of the test chamber. Vacuum unit is completed with a vacuum forepump of rotary vane type 2NVR-5DM and a diffusion pump, maintaining pressure within the chamber from 760 to 10<sup>-4</sup> mm of mercury column. The chamber can be filled with gases. The pressure measurements are performed, in the range from 760 to 1 mm, by a vacuum-gauge of the accuracy rating 1.0 and in the range from 1 to 10<sup>-5</sup> mm by an ionization thermocouple vacuum-gauge VIT-2 equipped with manometric converters: thermocouple one PMT-2 and an ionization one PMI-2.

### RECORDING EQUIPMENT

Based on the analysis of spectral responses of photocathodes, we have chosen for light signals recording the photoelectric multiplier PMT-79, possessing multialkali photocathode and good time and amplitude responses in both red and violet portions of spectrum. Linear operation mode of a PMT was controlled in the range of recorded signals from 20 to 10<sup>4</sup> mV. The PMT assembly was supplied by a regulated power sources VS-22 ensuring stability not worse than 10<sup>-4</sup>, which met the required measurement accuracy.

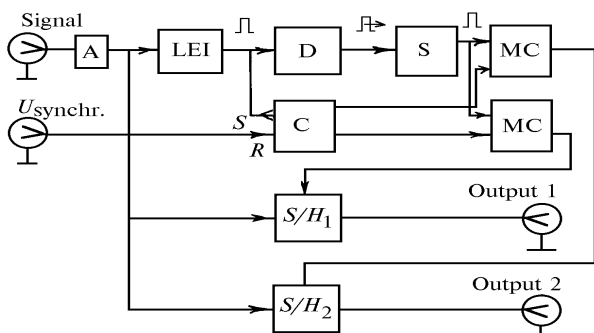


FIG. 2. Block-diagram of the processing unit: A is the scaling amplifier, LEI is the leading edge isolation device, D is the delay flip-flop, S is the pulse sampler, MC are the matching circuits, C is the clocked flip-flop, S/H<sub>1</sub> and S/H<sub>2</sub> are the sample-and-hold devices for operating and reference signals, respectively.

Electric signals from PMTs are amplified, stored and compared in the recording unit.

This unit possesses three identical processing channels according to a number of simultaneously recorded signals. The block-diagram of the unit is considered in more detail below for one of the channels (Fig. 2).

The functioning of the unit is arranged as follows. An electric signal in the form of a sequence of pulses 1, 2, 3, ...,  $n$  coming alternatively from operating (odd pulses) and reference (even pulses) channels at a fixed frequency is directed to a scaling amplifier A (Fig. 2). The frequency of pulses  $f_p$  is determined by the number of holes in the chopper and by the number of its revolutions per unit time. Amplification  $K_A$  could be varied from 40 to 100. At a given angular velocity and three/nine holes in the disc  $f_p$  appeared to be 100/300 Hz.

The amplified pulse comes further to two sample-and-hold devices S/H<sub>1</sub> and S/H<sub>2</sub> simultaneously and to the leading edge isolation device LEI. The latter one activates a delay flip-flop D. After it is triggered the signal comes to a pulse sampler S and further to matching circuits MC controlled by clocked flip-flop C. The pulses from LEI come to the reference input of C while the R (reset) input receives the clock pulse accompanying only operating signal. Delay of sampling pulse with respect to the leading edge of input pulse is necessary to exclude influence of transition processes. The sampling pulse after passing the corresponding matching circuit MC comes to triggering input of S/H devices.

As a result we get simultaneous S/H output of signals from reference and operating branches. Hence they can be compared by means of oscilloscope with the differential input. We used for this purposes an S1-91 oscilloscope.

### RESULTS OF TESTS

The whole of testing was divided into testing of vacuum equipment and that of signal recording unit.

At the first stage we checked the time necessary to reach the pressure in the test chamber on the order of 10<sup>-4</sup> mm of mercury column. After some adjustment we achieved the required pressure in 2 hours of pumps working which, in our opinion, is indicative of a good quality of assemblage and pumps operation.

At the second stage we checked the reliability of recording a minimum depth of light signal modulation while changing parameters of a gas in the test chamber. This value after numerous tests appeared to be about half percent of the measured value.

### CONCLUSION

In our opinion the designed setup can be used not only for investigation into the propagation effects of bimodal laser radiation in the atmosphere but also for solution of other problems on light scattering concerning, e.g., Raman scattering by polaritons in crystals at small angles with respect to the direction of propagation of exciting radiation.

### ACKNOWLEDGMENTS

The author is greatly indebted to A.A. Kozlov for helpful advices and practical assistance in development of the recording unit and assembling of the setup.

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