HYBRID AUTODYNE LIDAR

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A hybrid CO_2 laser with a pulsed and continuous gain sections in a single cavity has been used in an autodyne lidar.

It has long been known that power in a laser beam is affected by the reflection of a part of the output beam back into the laser cavity.[1] This effect has been used in atmospheric optics to measure wind velocities,[2] precipitation fall velocities[3] and for highly sensitive atmospheric spectroscopy.[4] Much attention in these papers was given to the analysis of performance characteristics of lidars with cw lasers. It was shown that autodyne lidars possess the set of properties such as high noise immunity and high sensitivity which make them promising for atmospheric optics applications. Churnside[5,6] showed that the detection sensitivity of such lidars could be enhanced in the course when the laser operated near threshold.

However, there is an internal contradiction in the basic idea of an autodyne lidar with cw laser since the more is an influence of a weak echo signal on the field within the cavity, the more is a distortion of the sounding beam. In particular, when a laser operates near threshold, a weak signal is transmitted, and consequently the range of sounding is short.

At the same time lidars using the pulsed lasers are convenient for a number of applications since information about distance can be obtained by measuring the time of flight, and the usage of short pulses allows one to operate with a strong probing signal which does not initiate nonlinear interactions in the atmosphere. We propose to use a hybrid laser as an autodyne lidar. In the hybrid laser, a cw and pulsed gain sections are placed in the same cavity. This configuration is used to amplify the selected longitudinal mode and widely used in heterodyne lidars.[7] The preliminary results presented here suggest that it can also be used to obtain the increased sensitivity in autodyne lidars.

The schematic diagram of the hybrid–laser geometry is shown in Fig. 1. The rear mirror is a total reflector with a 5–m focal length. The output coupler is a plane mirror with a reflectivity of 0.8. The cavity length is 2.5 m. The mode volume was limited by the aperture of the pulsed gain section so that only the TEM_{00} operation was ensured.

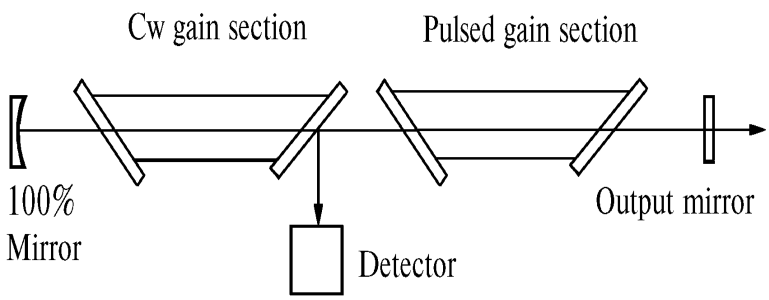

FIG. 1. Schematic diagram of the hybrid autodyne lidar.

The cw gain section was in the rear of the cavity. For preliminary laboratory experiments, it was a 1–m section of low–pressure CO_2 pumped by a longitudinal dc electrical discharge. At the ends of the cw section the ZnSe plates were mounted at Brewster's angle. A residual reflection from one of these plates was directed into the detector and used as the signal. Several watts of output power were obtained by pumping the cw section alone.

The pulsed gain section was in the front of the cavity. For the laboratory experiments it was 30 cm long with a cross section of 1×3 cm. This section was pumped by an electron beam under atmospheric pressure. With the unpumped cw section in the cavity we obtained 15 mJ in a 300–ns pulse and the repetition pulse frequency was as high as 4 Hz. A typical pulse shape is shown in Fig. 2 *a*, which is a copy of an oscilloscope trace. The zero–time reference is identical to the pumping pulse, so one can see in the figure a delay of about 1.3 μs and then a fairly smooth pulse.

When the cw section was pumped, the output pulse characteristics were modified, as can be seen in Fig. 2 *b*. Because the state of the system has been already above threshold, the delay between the *e*–beam pumping and the pulse almost disappears. In addition, the pulse length increased up to about 800 ns. These features (decreased build–up time and increased pulse length) were observed in the previous studies of hybrid CO_2 lasers.[8–11] The oscillations in the tail of the pulse can be caused by the interference of longitudinal modes as well as by influence of the pumping pulse. The similar phenomenon was observed by Likhanskii et al.[10] and found to be caused by spatial gain modulation. However, in our case the problem requires further study.

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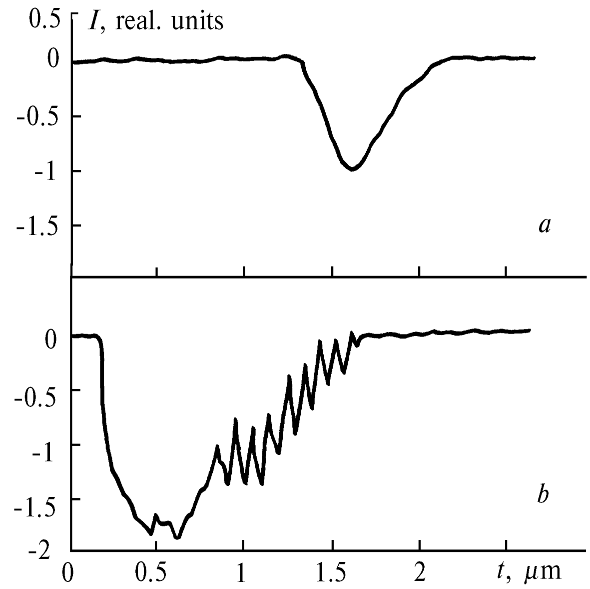

FIG. 2. Typical laser shapes of the detector with the cw section off (a) and on (b).

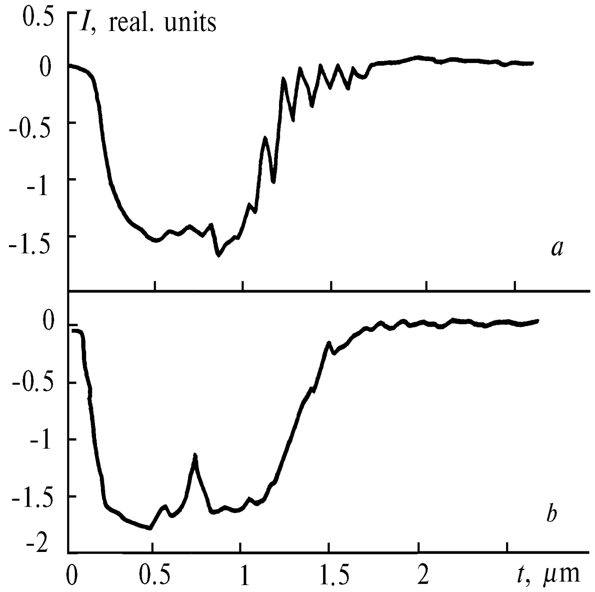

FIG. 3. Typical laser shapes of the output pulse with external feedback: for attenuation using 0 *(a) and* 30 dB *(b).*

In the laboratory experiments, feedback was provided with a pair of plane mirrors. The laser output was directed into the rear Brewster window of the pulsed section so that the reflected beam reached the cw section of the cavity. A typical pulse shape for this configuration is shown in Fig. 3 *a*. The addition of feedback led to lengthening the pulse and made the pulse power more uniform. In so doing the oscillations were suppressed. We decreased the amount of radiation returned to the cavity to 0.001 of its original small value with the help of an absorbers. A typical pulse shape under these conditions is presented in Fig. 3 *b*. As comparison showed, no significant differences were observed, and we infer that the response of the system to feedback was saturated at the levels of feedback that could be achieved in the laboratory experiments.

For measurements along longer paths the system was moved to another location. At the same time, the cw gain section was replaced by that with lower gain. This section was only 50 cm long and produced the power about 1 W in the hybrid configuration cavity when the pulsed section was unpumped. Also, a 30–cm diameter telescope was placed in front of the lasers and focused onto a mirror placed 400 m from the laser.

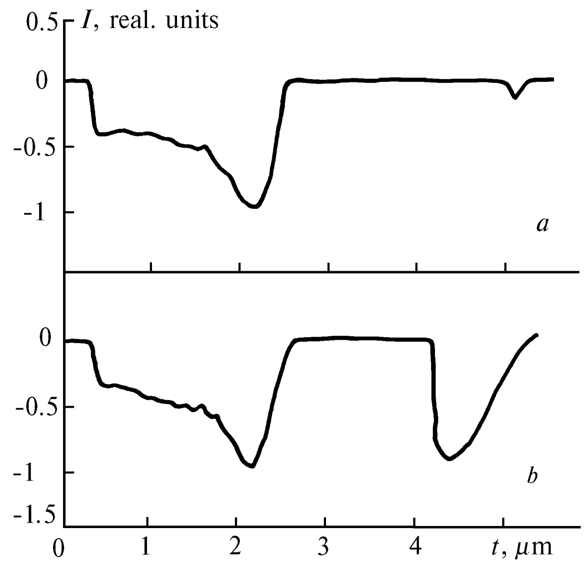

FIG. 4. Typical signal and echo signal from a mirror at 400 m *with the cw section off (a) and on (b).*

The system was first in operation with the unpumped cw section. Typical signals are shown in Fig. 4 *a*. Shown at the left of each trace is the output pulse whose shape differs from that obtained in the laboratory experiments due to the absorption losses in the cw section. The return from the target mirror can be clearly seen at the right of each trace. When the cw section was turned on, the return strongly increased. A typical trace is shown in Fig. 4 *b*. The apparent decrease in the time of signal propagation forward and backward is explained by the fact that in the latter case the echo signal is formed by the leading edge of the sounding pulse.

Thus we show that the hybrid autodyne lidar amplifies significantly the echo signal. The simple estimations show that the signal arrived to the detector at least is an order of magnitude larger than the echo signal being measured by direct detection. This fact makes the proposed configuration of the autodyne lidar promising for applications as well as for the study of redistribution of the energy within the hybrid laser cavity under action of the echo signal.

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