

AUTODYNE LIDAR BASED ON CW AND PULSED Nd:YAG LASERS

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In this paper we describe a system of optically coupled cw and pulsed Nd:YAG lasers making an autodyne lidar. We have studied a behavior of intensity of a lidar return injected into cw laser operated in different modes. It is shown that a lidar based on cw and pulsed Nd:YAG lasers is highly sensitive to the return signal injected into an autodyne lidar.

The model of a hybrid autodyne lidar based on a CO₂-laser and combined advantages both of autodyne cw²⁻⁵ and pulsed⁶ lidars was suggested in Ref. 1. It was shown that hybrid configuration allows the sensitivity to the return signal to be enhanced significantly.

At present the solid-state lasers⁷ are widely used in lidars. In this connection we have studied a feasibility to create a cw-pulsed autodyne lidar based on Nd:YAG lasers. Complete copying of the hybrid scheme¹ was impossible in our case because of high power losses in sensing pulse caused by nonlinear losses in the cavity. To overcome this barrier, the optical scheme of the lidar was changed (see Fig. 1). In this case, we have to deal with optically coupled pulsed and cw lasers rather than hybrid one. New configuration allows the performance of experimental analysis of a behavior of the lidar return once it has been amplified and mixed. The role of pulsed and cw lasers in the return signal amplification and the role of cw laser in the process of the sensing pulse formation are of interest. The created lidar model is capable to measure the field in the cavity of both cw and pulsed lasers in following cases: 1) pulsed laser operation only, 2) pulsed lasing and the pre-threshold state of the cw laser, and 3) joint lasing of both lasers.

Quasi-continuous Nd:YAG laser with continuous pumping, $\lambda = 1.06 \mu\text{m}$ wavelength, threshold current $\approx 28 \text{ A}$, the average lasing power for the given cavity about 6 W, and cavity mirrors covered by dielectric sputtering was used in the model.

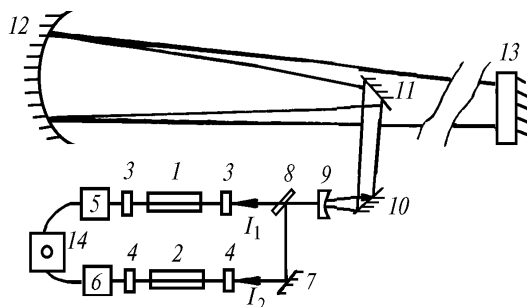


FIG. 1. Block-diagram of the experimental setup: Nd:YAG cw (1) and pulsed (2) sections, cavity mirrors of cw (3) and pulsed (4) lasers, PEM photodetectors (5 and 6), turning mirror (7), plane-parallel plate with 90% transmission and 10% reflection for $\lambda = 1.06 \mu\text{m}$ (8), telescope lens with 2% reflection (9), telescope turning mirrors (10 and 11), large telescope mirror (12), reflector (13), and S9-4A oscillograph (14).

Maximum pulsed frequency of the pulsed Nd:YAG laser was approximately equal to 15 Hz, the wavelength was $\lambda = 1.06 \mu\text{m}$, the pulse duration was $\approx 10 \text{ ns}$, the cavity mirrors were covered by dielectric sputtering. The Newton telescope was used in the model, and the reflector was placed at the distance of 75 m from the emitter. The lidar return recording was carried out with the two detectors 5 and 6 (see Fig. 1). Three modes of the model operation have been studied.

In the first case the pulsed laser operated solely, whereas the cw laser was off. To protect the detectors 5 and 6 from the power radiation, several fluoroplastic plates attenuated radiation were placed in front of their windows.

The signal oscillograms recorded with the detectors 5 and 6 are shown in Figs. 2a and b, respectively. In both cases the oscillograph operated in the same mode. It is seen from comparison the Figs. 2a and 2b that the amplitude of lidar return is 3.8 times greater in Fig. 2b than that in Fig. 2a. Let I_0 is the total amplitude of the lidar return (Fig. 1); I_1 is the part, falling on the cw laser 1; I_2 is the part, falling on the pulsed laser 2. Because the plate 8 transmits 90% of the intensity and reflects 10%, i.e., $I_2 = 9I_1$, hence, under the assumption of linear relation between input and output signals of both lasers, the amplitude of the laser return recorded with detector 6 may be thought of as 34.2 times greater than that recorded with detector 5.

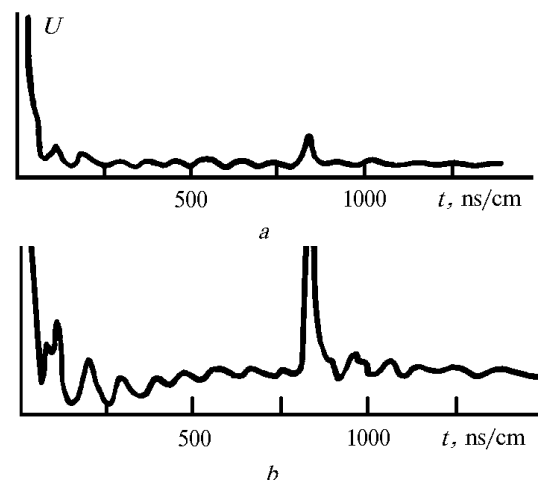


FIG. 2. The signal and return signal oscillograms recorded with detector 5 (a) and detector 6 (b). Pulsed laser operated solely, the cw laser was off.

In the second case both pulsed and cw lasers operated, but the cw laser operated in the pre-threshold mode. Figures 3a and b show the signal oscillograms recorded with detectors 5 and 6, respectively. The operating mode of the oscillograph was the same as in the first case. It is seen that the return signal amplitude in Fig. 3a is two times higher in comparison with that in Fig. 2a, i.e., the cw laser is a good amplifier when it operates in pre-threshold mode. It was tested experimentally that change of pumping current in cw lasing region does not change significantly the return signal amplitude. It is also seen from comparison of Figs. 2b and 3b that the return signal amplitude in Fig. 3b is 1.1 time greater than that in Fig. 2b. It is possible to enhance coupling between the lasers by selection of the dividing plate 8. Conceivable it could cause better results.

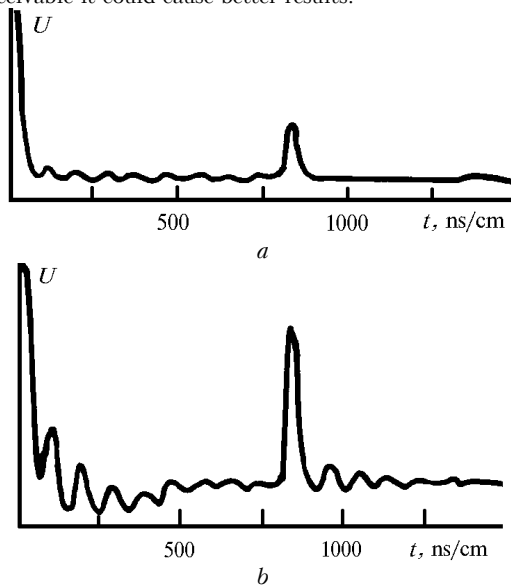


FIG. 3. The signal and return signal oscillograms recorded with the detector 5 (a) and detector 6 (b). Both lasers operated (the cw laser operated in the pre-threshold mode).

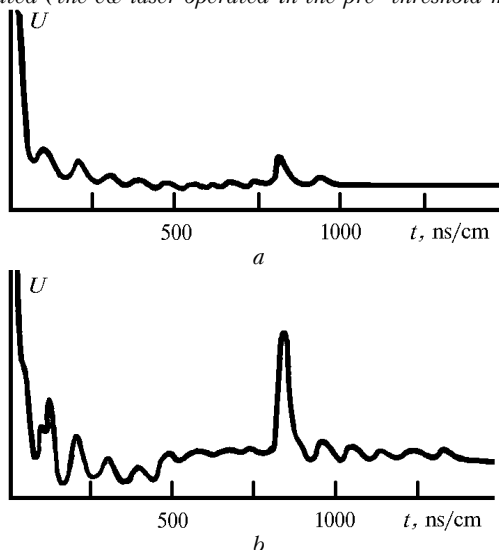


FIG. 4. The signal and return signal oscillograms recorded with the detector 5 (a) and detector 6 (b). Both lasers operated (the cw laser operated in the lasing mode).

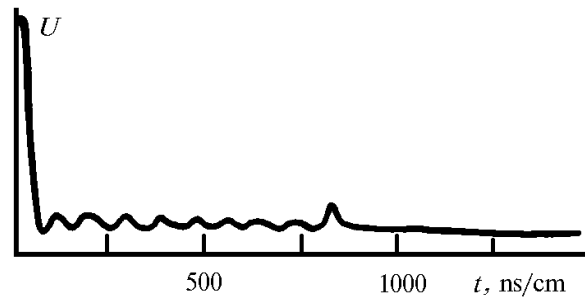


FIG. 5. The signal and return signal oscillograms recorded with the detector 5 (Nd:YAG crystal was removed from the cw laser).

In the third case the cw laser operated in the lasing mode. The oscillograms of signals recorded with the detectors 5 and 6 are shown in Figs. 4a and b, respectively. It is seen that the return signal amplitude in Fig. 4 is lower than that in Fig. 3, i.e., the cw laser can be a good amplifier only when it operates in the mode of the pre-threshold lasing.

For comparison, the Nd:YAG crystal was removed from the cw laser, and signal was recorded with the detector 5. Figure 5 shows the oscillogram recorded in this case. The oscillograph operated in the same mode as in previous cases. The return signal amplitude was found to be lower than that at the presence of Nd:YAG crystal. It is seen that the return signal amplitude is 7 times smaller in Fig. 5 than that in Fig. 3b. So, taking into account that $I_2 = 9I_1$, it turns out that the return signal obtained for the case of pre-threshold operation of cw laser (Fig. 3b) is amplified by the factor of 63 in comparison with the case presented in Fig. 5.

Thus, it is shown in the paper that the cw-pulsed autodyne lidar based on Nd:YAG lasers is highly sensitive to the return signal. This fact makes the suggested configuration of the autodyne lidar to be promising for further studies aimed to reach the maximum in sensitivity and then to develop the model of a high-sensitive atmospheric spectrometer.

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