Fig. 2. Room-temperature fluorescence spectrum (1) and laser oscillation spectra (2, 3, 4) of Nd$^3^+$ ions in 68.5%SrF$_2$:30%LaF$_3$:1.5%NdF$_3$ crystal at 748-nm excitation wavelength.

Fig. 3. Room-temperature fluorescence spectrum (1) and laser oscillation spectra (2, 3, 4) of Nd$^3^+$ ions in 68.5%SrF$_2$:30%LaF$_3$:1.5%NdF$_3$ crystal at 747-nm (2), 744-nm (3), and 742-nm (4) excitation wavelengths.

properly selected pumping wavelength. The laser oscillations data for other studied crystals will be presented. This work was supported in part by AT&T Bell Labs.

Lidar and Remote Monitoring II: New Lidar Techniques

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Fig. 1. Model of the maximum-resolved lidar profile $\Phi$ vs sample number, used in the simulations; the sample rate corresponds to a range cell of 15 m.

Fig. 2. Ratio $\chi = \delta_\Phi / \delta_\Omega$ of the errors $\delta_\Phi$ and $\delta_\Omega$ corresponding to two random deviations with standard deviation $\sigma_\Omega = 0.3$ and correlation times $\tau_\Omega = 0.3$ ms and $\tau_\Phi = 0.9$ ms. The level $\tau_\Omega/\tau_\Phi$ is 0.58 given by a horizontal line.

On the accuracy of rectangular-pulse deconvolution of long-pulse lidar profiles

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If a lidar system emits long rectangular sensing pulses, the lidar return signal $F(t)$ at the moment $t$ after the pulse emission will have low resolution and will be described by the equation

$$F(t) = \int_{0}^{t} \Phi(t) \, dt$$

where $c$ is the speed of light, $\Phi(t)$ is the maximum-resolved (6-pulse) lidar profile, and $\Phi(t)$ is the rectangular-pulse duration. The height of the rectangular-pulse shape is assumed to be equal to unity. In order to improve the lidar resolution, we have developed earlier a simple recurrence algorithm, inverse Eq. 1 with respect to $\Phi(t)$, namely

$$2/\Omega \int_{0}^{\infty} \Phi(t) \, dt - \Phi(t - \infty) = \Phi(t)$$

where $\Phi(t)$ is supposed to be known in some $c/2$-long initial interval and $F(t)$ is the first derivative of $F(t)$. Besides simplicity another feature of this algorithm is that it is not so sensitive to noise as compared to other deconvolution algorithms we have developed. In this work we estimate the error caused by rectangular-pulse approximation of various sensing laser pulses in order to outline the conditions under which this approximation is acceptable, and, consequently, useful because of its advantages. A real pulse shape $S(t)$ may be written in the form

$$S(t) = \delta(t) + \delta(t)$$

where $\delta(t)$ is an approximating rectangular shape $\delta(t) = 1$ for $t \in [0, \Omega]$, and $\delta(t)$ is $0$, and $\delta(t)$ is a deterministic or random deviation with respect to $\delta(t)$. Because of this deviation an error arises $\delta_\Omega = \Phi(t) - \Phi(t)$ in the restoration of $\Phi(t)$, where $\Phi(t)$ is the restored, on the basis of algorithm (2), short-pulse lidar profile.

A theoretical analysis of $\delta_\Omega$ for various types of deviations, such as finite rise and decay times, spikes, random deviations, etc., shows that when their potential contribution to the integral (1) is small compared to the true-pulse contribution, the error $\delta_\Omega$ may have a reasonable value. An interesting consequence of this is that in the case of a random deviation with standard deviation $\sigma_\Omega$, and correlation time $\tau_\Omega$, less than the least variation scale of $\Phi(t)$, the error $\delta_\Omega$ is proportional not only to $\sigma_\Omega$, but to $\sigma_\Omega^2$ as well.

The simulations performed support the theoretical conclusions. The used lidar profile is given in Fig. 1. The true-pulse shapes involving the above deviations and used for determination of $F(t)$ are constructed according to Eq. 3. The deconvolution is performed according to the recurrence algorithm (2) using a rectangular-pulse approximation. As an example, in Fig. 2 we have represented the ratio $\chi = \delta_\Phi/\delta_\Omega$ of the errors $\delta_\Phi$ and $\delta_\Omega$ corresponding to two random deviations.
with correlation times $\tau_1$ and $\tau_2$. It is seen that $x(2)$ oscillates around $(\tau_1, \tau_2)^{1/2}$. In general the rectangular-pulse algorithm is effective in the case of sufficiently small deviations.

In the case of large deviations the error $\delta_0$ might have considerable and not acceptable values. Then, the influence of random deviations can be eliminated by averaging over a sufficient number of laser shots. For deterministic deviations the rectangular-pulse approximation may be used again, but the corresponding deconvolution algorithm will be effective only as a first step of an iterative procedure leading to the correct profile $\Phi(2)$. The convergence of the procedure in various cases as well as some numerical variants of its realization are investigated.


**CFD3 (Invited)**

**Recent progress in coherent lidar**

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Summary not available.

**CFD4 (Invited)**

**Potential of autodyne lidars for study of the atmosphere**

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Nowaday usage of laser autodyning, i.e., usage of a laser as a transmitter of probing signal and as the receiver of its frequency shifted echo, is quite attractive area for the lidar community (see, for example, Ref. 1). Such an approach to laser sensing of the atmosphere looks very beneficial since information on atmospheric path losses and on retroreflector (mirror, topographic targets, aerosol) properties is retrieved from characteristics of the laser intracavity field. As a result of intraresonator mixing, the following positives take place: (1) high noise immunity; (2) enhanced sensitivity quite comparable with those achieved at heterodyning; (3) possibility to neglect by short noise of a photodetector; (4) simple lidar design since the same optical path is used for the probing signal and its echo; (5) absence of local oscillator, hence robustness and self-alignment of the lidar; (6) possibility to retrieve a set of optical and dynamic characteristics of the distant retroreflector and atmospheric path from signal measurement.

Basic physics of laser detection of weak signals providing the mentioned positives of autodyne lidars is discussed briefly. A description of the set of designed laboratory version of autodyne lidars illustrating reach of the listed above features is also given.

The set includes cw CO$_2$, multipurpose lidar, solid-state (Nd:YAG) aerosol lidar and two laboratory setups of novel versions of autodyne lidars, so-called hybrid lidars. The latter combines cw and pulsed gain sections in the same resonator and benefits from all positives of cw laser autodyning as well as from features inherent to pulsed lidars.

Experiments performed with CO$_2$ hybrid lidar and with the lidar on coupled cw and pulsed Nd:YAG lasers shows perspectivity of such an approach and indicates basic design concepts for a robust multipurpose lidar with enhanced sensitivity and enhanced range of operations.


**CFD5**

Fig. 1. Laser ceilometer backscatter lidars measure cloud height and vertical visibility at most major airports.