N87-10360

COHERENT LIDAR SIGNAL FLUCTUATION REDUCTION BY MEANS OF FREQUENCY DIVERSITY TECHNIQUE

R. M. Schotland, P. Vujkovic Cvijin* and Yan-Zeng Zhao
University of Arizona, Tucson, Arizona 85721

The atmospheric return measured by a coherent lidar is typically characterized by rapid and deep fluctuations in signal strength. These fluctuations result from the interference of the fields backscattered to the lidar from randomly located aerosol particles which move relative to the lidar pulse. In many applications, it is necessary to determine the average value of the lidar signal intensity at some range. The usual procedure employed is to average N uncorrelated measurements from this range and then, under the assumption that the system statistics are stationary, assume that signal uncertainty improves inversely with the square root of N (for large carrier to noise ratios). Because of the large number of independent samples required to obtain accurate intensity estimates, consideration was given to an alternate method to obtain additional independent samples. The method utilizes frequency diversity initially suggested by Goldstein [1] and subsequently studied in the microwave radar domain by Marshall and Hitschfeld [2] and by Nathanson and Reilly [3]. The idea has apparently not yet been applied to coherent lidar. It is expected that the application of the frequency diversity method in the coherent lidar domain will eventually provide greater efficiency and speed in the return signal averaging needed to obtain accurate intensity estimates.

The frequency diversity method recognizes that the transmitted lidar pulse is very long compared to a wavelength and consequently a given phase, θ_i, is repeated many times within the pulse. The backscattered signal corresponding to θ_i samples those aerosols located in range corresponding to θ_i. If the frequency is increased so that an additional wavelength is contained within the lidar pulse then θ_i will be redistributed over the pulse volume and consequently sample a new set of aerosol particles [2].

In order to test this concept, a fairly simple laboratory experiment has been designed which, to a degree acceptable for this purpose, simulates scattering of a lidar pulse from atmospheric aerosol. The purpose of the experiment is to compare the standard deviation of the signal fluctuation in two cases: the first, when the laser is allowed to operate on a single line and second, when the laser operates on two lines

---

* Permanent address: Institute of Physics, P.O. Box 57, 11001 Belgrade, Yugoslavia.

sufficiently separated to provide a test of frequency diversity.

In the experimental apparatus shown in Fig. 1 the beam from a continuous wave CO_2 waveguide laser is aimed at an aluminum disk whose edge has been uniformly roughened and whose rotation provides the Doppler-shifted frequency of the scattered radiation. A portion of the laser beam is diverted to a concave mirror and serves as a local oscillator beam. This beam is then heterodyned with the collected scattered radiation (signal beam) at the surface of a photoconductive HgCdTe detector. The scattering of light from an extended rough surface which introduces path differences greater than one wavelength is statistically similar to that from atmospheric aerosols distributed over a large volume.

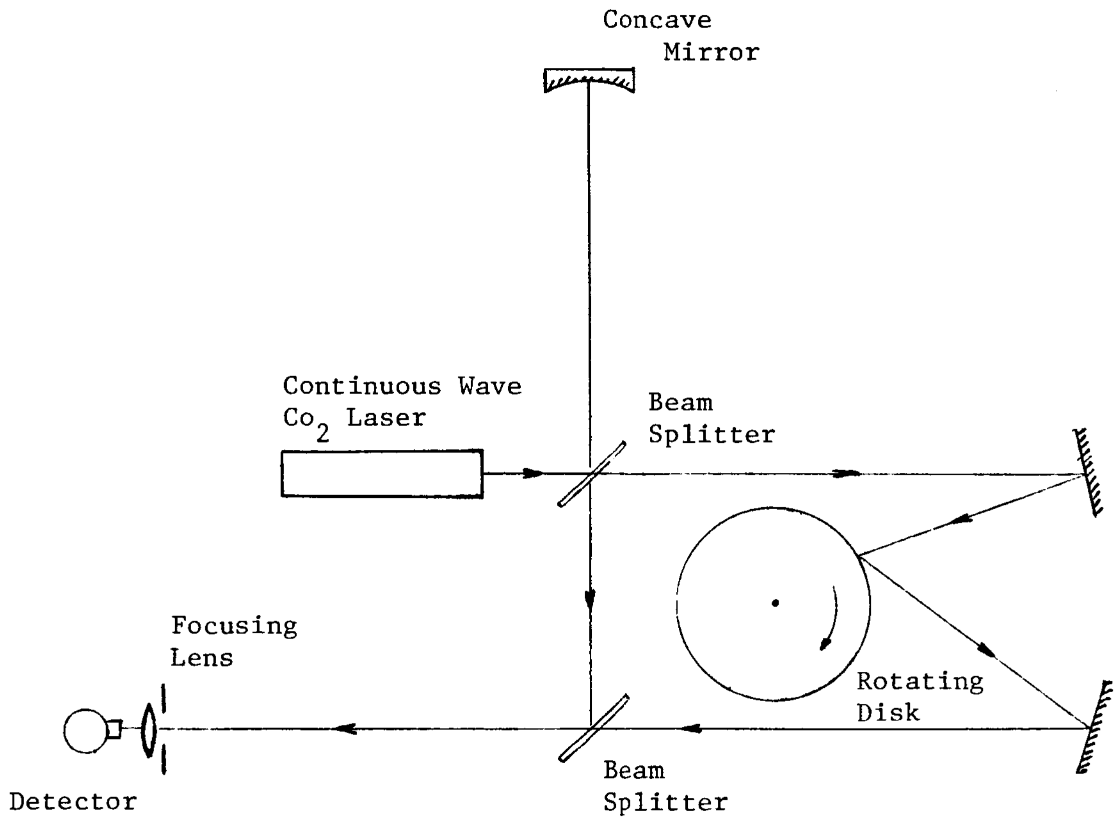

Fig. 1 Apparatus designed to test the frequency diversity concept in a laboratory experiment.

The CO_2 laser is deliberately tuned to operate simultaneously at two vibrational-rotational lines in the R branch of the 9 μm band with the frequency separation between the two lines approximately being 4×10^{10} Hz. For this case, if the product of the effective depth of the target L and the frequency difference $\Delta\nu$ satisfies the relation $L\Delta\nu \geq c$, where c is the speed of light, then independence of the scattering at these two frequencies is provided. It is important to note that the illuminated spot at the rotating disk in Fig. 1 has spatial extent, L, in the direction of receiver's axis. Owing to the large frequency separation between the two components of the transmitted radiation the minimum depth of the target required to obtain independent return signals is only L = 7.5 mm. This is easily provided in laboratory by the experimental setup of Fig. 1.

The signal processing is performed in the following manner. The preamplified output of the radiation detector on Fig. 1 is filtered, envelope detected and digitized by a 10 bit, 10 MHZ waveform recorder. The waveforms acquired are then transferred to a computer for further analysis. Based on the frequency diversity concept, the contrast C (the ratio of the standard deviation of the heterodyne signal to its mean value) in the dual line case is expected to have the value $C = C_1/\sqrt{2}$ where C_1 is the contrast for the single line case. Decrease of the contrast when the laser is operating at two lines simultaneously in comparison to single line operation has been proven experimentally. The amount of decrease in the value of contrast has been somewhat corrupted by inherent fluctuations of the output of the waveguide CO_2 laser whose cavity has been critically adjusted to provide lasing at two vibrational-rotational lines simultaneously.

References

1. Goldstein, H.: "The Origin of Echo Fluctuation," in "Propagation of Short Radio Waves" edited by D. Kerr, New York: Dover, 1951.

2. Marshall, J. S. and Hitschfeld, W.: "Interpretation of the Fluctuating Echo From Randomly Distributed Scatterers," Can. J. Phys. 31, 962, (1953).

3. Nathanson, F. E. and Reilly, J. P.: "Radar Precipitation Echoes," IEEE Trans. Vol. AES-4, No. 4, 505 (1968).