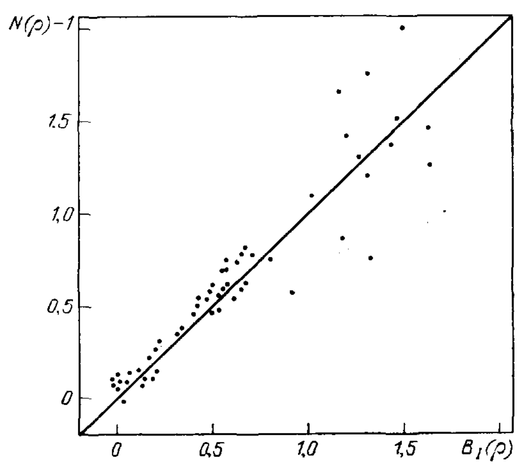

FIG. 2

medium (for sound waves). The enhancement will occur given any extended scatterer with a sufficiently broad scattering indicatrix. For example, Ref. 2 used a sheet of typing paper for the scatterer.

In the case of light focusing in the atmosphere the backscattering enhancement factor N can exceed unity severalfold. In Fig. 2 we plot experimental data obtained by Kashkarov for laser radiation in the atmosphere over paths of 650 and 1300 m.[3]

The backscattering enhancement effect will occur with any type of wave. It is observed in the sonar probing of the atmosphere and the ocean, in radio wave scattering in the ionosphere, cosmic, and laboratory plasma, in seismoacoustic probing, in electron scattering from complex molecules, and so forth. Reviews of published studies are available in Refs. 4 and 5.

Similar and even more pronounced enhancement effects can take place in scattering from bodies situated behind a random phase screen[1] or near a rough interface between two media. This last phenomenon was predicted in Ref. 6 and then experimentally confirmed by laser probing of the ocean (see the report of A. A. Apresyan and D. V. Vlasov below). Related to the discussed phenomena are the long-range correlation effects and partial wave front reversal in randomly inhomogenous media, discussed below by A. N. Malakhov, A. V. Polovinkin, and A. I. Saichev.

Finally, the enhancement phenomenon is also related to the multichannel coherence effects that can occur when waves are scattered from an ensemble of scatterers.

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A. N. Malakhov, A. V. Polovinkin, and A. I. Salchev. *Partial wave front reversal in a randomly inhomogeneous medium.* In the case of backscattering or reflection in an inhomogeneous medium there may exist a multitude of coherence channels through which different components of a wave travel in opposite directions. Their mutual coherence leads to specific effects which do not occur when waves propagate and scatter predominantly in one direction. Such effects are at their most obvious in the case of reflected waves which pass twice through the same inhomogeneities in the medium, as in the case of optical waves reflected by a turbulent atmosphere. One notable effect is that of partial reversal: the field of the reflected wave contains a component whose wave front is partially reversed with respect to the wave front of the incident wave.

Let us clarify the mechanism of partial reversal in the simplest case of a wave emitted in an inhomogeneous medium by two mutually coherent point sources located at $\mathbf{R}_1$ and $\mathbf{R}_2$. The wave is reflected by a point reflector at $\mathbf{R}_0$ (Fig. 1). The complex amplitude of the reflected wave's field at an arbitrary point $\mathbf{R}$ is

$$v(\mathbf{R}) = fg(\mathbf{R}, \mathbf{R}_0)\,[u_1 g(\mathbf{R}_1, \mathbf{R}_0) + u_2 g(\mathbf{R}_2, \mathbf{R})];$$

where u_1 and u_2 are the complex amplitudes of the source waves, f is the reflection coefficient, and $g(\mathbf{R}',\mathbf{R}'')$ is the Green's function for the wave. The coherence channel illustrated in Fig. 1 results in the reflected wave having mutually coherent components in the vicinity of both sources

$$v_0(\mathbf{R}_1) = fu_2 g(\mathbf{R}_1, \mathbf{R}_0)\, g(\mathbf{R}_2, \mathbf{R}_0),$$
$$v_0(\mathbf{R}_2) = fu_1 g(\mathbf{R}_2, \mathbf{R}_0)\, g(\mathbf{R}_1, \mathbf{R}_0),$$

the phases of which are reversed with respect to those of the source waves. Indeed, let the initial source wave phases be S_1 and S_2. By reciprocity, when these waves travel via the same coherence channel in opposite directions they acquire the same phase factor S_{12}. Thus

$$v_0(\mathbf{R}_1) \sim \exp[j(S_2 + S_{12})],\quad v_0(\mathbf{R}_2) \sim \exp[j(S_1 + S_{12})].$$

Since $S_2 + S_{12} = -S_1 + S$, $S_1 + S_{12} = -S_2 + S$ then, up to an overall phase factor $S = S_1 + S_2 + S_{12}$ the phases of the reflected wave's coherent components at $\mathbf{R}_1$ and $\mathbf{R}_2$ are $-S_1$ and $-S_2$ respectively, i.e., reversed with respect to the initial source phases.

If the medium contains many coherence channels then many field components with reversed phases combine into a

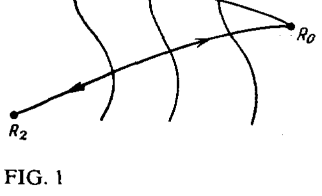

FIG. 1

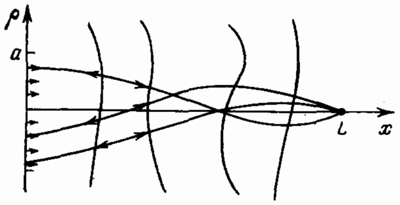

FIG. 2

reversed component in the field of the reflected wave. For example, suppose a collimated beam of radius a and complex amplitude $u(\rho)$ is radiated in the $x = 0$ plane and at a distance L from the source plane a point reflector (Fig. 2) is located in the multiple ray propagation region for the source wave, such that $N = \sigma/\rho_k \gg 1$ (where ρ_k is the source wave's radius of coherence in the vicinity of the scatterer and $\sigma = L/k\rho_k$ is the characteristic transverse deflection of the ray from its trajectory in a homogeneous medium). If $a > \rho_k$ then in the vicinity of the source the reflected wave will contain a reversed component with the average amplitude of approximately $v_0(\boldsymbol{\rho}) \approx (\rho_k/a)^2 u^*(\boldsymbol{\rho})$. If $a \leqslant \rho_k$ the reversed component is focused, leading to the enhancement of the reflected wave intensity in the vicinity of the source. When $a > \rho_k$ this enhancement of intensity can also be observed in the focal plane of a lens positioned to coincide with the source: the lens will effectively focus the weak, but spatially strongly coherent reversed comonent of the scattered wave. Let us emphasize that given $N \gg 1$ the reflected component reversed with respect to the source wave will be present in all space between the source and the reflector, albeit far from the source its spatial coherence, like the coherence of the incident wave, will be weak. Also, multichannel coherence effects analogous to partial reversal should exist in regularly-inhomogeneous media, as well as in the case of waves reflected from complex shapes in a homogeneous medium.

The reciprocity of waves that causes the partial reversal effect also governs the behavior of waves reflected from phase conjugation systems, such as phase front reversal (PFR) mirrors. We note some of the features of this phenomenon in the example of a wave point source (light spot) from a reflected in a turbulent medium from a PFR mirror of radius a, located at a distance L from the source. If $a > \sigma$, the directivity diagram of the PFR mirror $\sim 1/ka$ will be smaller than the coherence angle ρ_k/L and the distortions introduced into the reflected wave by the turbulence will be almost fully compensated by the mirror. The reflected wave will be focused to a spot of radius L/ka in the plane of the source. If $a < \sigma$, we do not have a full compensation of the effect of the inhomogeneous medium. If $N \gg 1$ in the latter case, the mean intensity of the reflected wave in the plane of the source will consist of a sharp intensity peak of the reversed component superimposed on a broad ($\sim \sigma$) plateau. The peak's radius will be $\sim \rho_k < L/ka$. The indicated narrowing of the intensity peak can be treated in terms of the turbulent medium broadening the effective dimensions of the PFR mirror to a radius $\sim \sigma$.

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L. A. Apresyan and D. V. Vlasov. *Strong double passage effects in laser probing of the upper ocean layer.* The great promise of airborne lidar systems in the probing of the upper ocean layer (UOL) is due to the availability of clear reference signals due to molecular scattering in the water column (particularly spontaneous Raman scattering (SRS)) which can be studied in the laboratory. Reference signals enable us to measure "impurities per water molecule" irrespective of the lidar type and aircraft, and hence to compare quantitatively the data gathered by different systems. Field experiments on the laser probing of the UOL, carried out by the AOL team[1] (U.S.) on the "Chaika" airborne lidar[2] (Institute of General Physics, USSR Academy of Sciences) as well as a number of other teams, turned up anomalous resuls which could not be explained by the widely used echo-signal parameter measurement model and thus cast doubt on certain important measurement techniques. An analysis of these results led us to the conclusion that there are strong echo-signal fluctuations due to the focusing and defocusing that occurs during the double passage of radiation through the disturbed air-water interface.

In the standard model the time base of the SRS reference signal should fall monotonically with increasing depth. Experiments[1,2] however measured nonmonotonic distortions and giant bursts in the SRS signal. Hoge and Swift measured a strong correlation of echo-signal fluctuations with local disturbances in the UOL.[1] When measuring echo-signal fluctuations from two depths, Vlasov obtained a strong anticorrelation in several ensemble realizations (Fig. 1). These, as well as other anomalous experimental results, suggest that surface disturbances must be taken into account when we interpret the results of UOL laser probing. Generally, the echo-signal power $P_S(z_S)$ from isotropic scatterers in the z_S plane behaves as $P_S(z_S) \propto \int I_L I_S d^2\rho_S$ where, omitting the proportionality constant, we have I_L and I_S as the radiation intensities at the scattering point z_S, $\boldsymbol{\rho}_S$) for a unit source and a receiver acting as a unit source, respectively. Because of the integration over ρ_S the measured power P_S