of the laser radiation (a narrow-band interference filter is placed in front of the receiver to cut out all noise outside of its passband); 4) the possibility of selecting the beamed object; 5) sounding does not disturb the medium sounded; 6) remote determination of the profiles of the various components.

The above advantages not only make possible quantitative determination of the concentrations of various atmospheric pollutants, but also permit detailed study of the dynamics of pollution processes.

All atmospheric pollutants belong to either of two classes: 1) aerosols (industrial hazes in particular), and 2) gases.

The phenomenon of aerosol scattering is used in aerosol sounding. The lidars that have been built and tested thus far reliably register laser-pulse echo signals that can be analyzed to extract information on the space and time distributions of industrial haze particle concentration with certain assumptions as to the particle size spectra. Below we shall review the possibilities for the additional extraction of data on the concentrations and particle size spectra without use of a priori information.

Gases polluting the atmosphere can be sounded by any of the following methods: 1) recording the echo signals of laser pulses the radiated wavelength in one of which coincides with the center of an absorption line of the gas being sounded, while the wavelength of the second pulse is not far from that of the first, which is not subject to absorption; 2) registration of laser-pulse echo signals at combination frequencies, which are different for each gas; 3) use of the resonant-scattering phenomenon.

The ceiling for laser sounding of atmospheric pollutants is determined on the one hand by the parameters of the lidar (pulse energy, receiving-dish diameter, passband and transparency of interference filter, bandwidth and sensitivity of display, etc.) and on the other hand by the concentrations of the pollutants and the interaction cross section. In industrial-haze sounding, one lidar with relatively modest parameters (ruby-laser pulse energy on the order of 1 J, receiving-dish diameter 0.5 m, interference filter half-width 10 Å at 50% transmission, display by a photomultiplier hand-picked from stock) can produce a space-time picture on the scale of the atmosphere of a large industrial city. The same lidar can be used to determine the concentrations of the gases directly at their sources (factory stacks, etc.) when Raman scattering is used. Two-frequency sounding offers substantially higher sensitivity.

The materials on which the paper was based have been published or submitted for publication: V. E. Zuev, Priroda, No. 10, 86 (1972); Problems of Laser Sounding for Atmospheric Parameters, Vestn. Akad. Nauk SSSR (1974); Lazer pokoryaet nebo (The Laser Conquers the Sky), Novosibirsk, Zapadno-Sibirskoe Khizhnoe Izdatel'stvo, 1972; Lazer-meteorolog (The Laser Meteorologist), Gidrometeoizdat, Leningrad, 1974.

G. A. Askar'yan, E. K. Karlova, R. P. Petrov, and V. B. Studenov. Vaporization, Burning Off, and Confinement of Oil and Other Films on Water Surfaces with the Aid of Powerful Laser Beams. The problem of clearing water surfaces of films of petroleum, oils, and other pollutants is of great practical interest. The paper[1] reported studies of the vaporization and burning off of such films on water by means of the beam from a power-

ful infrared laser used to scorch the surface. The use of infrared lasers in this application is most effective because of the short absorption path in the liquids ($l_a = 10^{-2}-10^{-3}$ cm for a CO_2 laser radiating at $\lambda \approx 10\ \mu m$) and the high average powers developed in gas and gasdynamic lasers. These factors make possible strong heating of a thin surface layer over large areas with a small specific consumption of energy. Let us estimate the temperature of the burn. Given a surface energy density $q_1 \approx It$ from an absorbed flux of density I, the burn temperature under prevaporization conditions will be $T \approx q_1/C\rho l$, where $C\rho$ is the heat capacity of $1\ cm^3$ of the medium, l is the thickness of the heated layer, $l \approx \sqrt{l_a^2 + \kappa t}$ (l_a is the absorption depth and κ is the thermal diffusivity.

If $l_t = \sqrt{\kappa t} \ll l_a$, we have $l \approx l_a$ and $T \approx q_1/C\rho l_a$. For example, with $C\rho = 4$ J, $l_a \approx 10^{-2}-10^{-3}$ cm, and $T \approx 300°C$ we obtain $q_1 \approx C\rho l_a T \approx 10-1$ J/cm².

If the heating time is not small and $l_t = \sqrt{\kappa t} > l_a$ (with $\kappa \approx 10^{-3}$ cm²/sec and $l_a \approx 10^{-3}$ cm, this is the case for $t \gtrsim 10^{-3}$ sec), we have $T \approx I \sqrt{t}/C\rho\sqrt{\kappa}$.

For example, we obtain $T \approx 300°C$ with $I \approx C\rho T\sqrt{\kappa}/\sqrt{t} \approx 30/\sqrt{t} \lesssim 30$ W/cm² if $t > 1$ sec, i.e., conditions adequate for strong vaporization or burnoff of the polluting layer can be created in comparatively simple fashion.

Experiments were set up in which a water surface was cleared of a polluting film. A film of kerosene, oil, petroleum, or some other material was formed on the surface of the water and the beam of a CO_2 laser was directed at it. Two types of lasers were used: a continuous laser with powers up to 50 W and a pulsed laser with a power of ≈ 1 MW, a pulse energy ≈ 1 J, and a repetition rate of 2 Hz. The unfocused beam was 12 mm in diameter; focusing by a lens of focal length $F \approx 30$ cm reduced the size of the beam spot to $1-2$ mm ($r \sim F\varphi$, where the divergence angle $\varphi \sim \lambda/a \sim 2 \times 10^{-3}$ rad).

Strong vaporization, smoking, and burning off of the film were observed in the focused beam in both cases. If the film was thin (for example, a kerosene layer thinner than 1 mm), strong spattering and noise were observed and became more intense when the beam struck the surface of water that had been cleared of the polluting film. Since kerosene and gasoline absorb ten-micron radiation more weakly than does water, the noise and spattering were weaker when the beam struck a thick layer (the dark-colored petroleum fractions have larger absorption coefficients, and the processes described above take place more vigorously).

When the unfocused beam of the continuous laser was used on a layer of pure kerosene, we observed a mass decrease $dM/dt \sim 0.4$ g/min at a 50-watt power flux and a beam-spot area of 1 cm². The mass decrease of the layer was determined from the decrease in its thickness when observed from the side and from the decrease in the weight of the cell with water coated with a layer of kerosene. (To prevent heating of the cell as a whole, it was placed in a large water bath, from which it was removed for weighing or measuring.)

The flux density used in the unfocused beam was near that obtainable from a powerful modern gasdynamic laser at a spot area of 1 m². This area can easily be made hundreds and thousands of times smaller. The density used in the focused beam was comparable to the

flux density from a gasdynamic laser with a spot area of 100 cm².

We note that in our experiments, the luminous energy drawn from the continuous beam to vaporize a unit mass of light kerosene was 10^4 J/g, which is much larger than the 700—100 J/g of heat required to boil and vaporize kerosene. The difference can be explained by the dissipation of heat in raising the temperature of the remaining mass of liquid.

The pulsed beam with a pulse duration of 1 μsec did not allow time for the heat released to leave the absorption layer during the pulse ($\sqrt{\kappa t} \ll l_a$), and the greater part of the energy went into vaporization. At a pulse energy of 1 J, a pulse duration ~1 μsec, and a 2-Hz repetition frequency in a partially focused beam with a spot 2 mm in diameter, we obtained vaporization of a layer of kerosene at dM/dt $\approx$ 0.05 g in 30 min; the energy consumed was 2400 J/g, or one-quarter of the amount used by the continuous beam.

The transition to short pulses, high powers, and more strongly absorbing pollutants could reduce the energy consumed in vaporization, not only by reducing the amount of energy used to heat the unvaporized liquid, but also due to ignition of combustible films. We note that pure surface absorption (with a heating depth of 10^{-5} cm) and flame combustion may occur at high power densities.

Burning of the films can be intensified by the addition of a small amount of a coloring agent or minute inhomogeneities that absorb the radiation and cause strong local overheating. This was observed experimentally on addition of various particles (corundum, sand, etc.) or dyes to the surface layer. Here the energy consumed to vaporize a unit mass of the layer was reduced to a fraction in an unfocused, unswitched beam.

A linear beam track on the surface of the liquid can be used to limit spreading and for boundary vaporization of the film along the confinement perimeter. Confinement by an extended beam track was studied. At a linear output of $\approx$ 20 W/cm in the continuous laser beam and a track width of ~1 cm, a sharp and stable boundary was drawn around the petroleum on the water surface. The confinement of spreading can be attributed not only to vaporization of the layer, but also to swelling, convective upwelling, and spreading of the heated water. These changes were easily observed visually on the water surface.

It is possible to clean up a layer of liquid by erupting or splashing it up off the water surface and then removing or collecting the spray. This kind of separation may involve vaporization of a thin layer of water under the layer of kerosene, which does not absorb as strongly as the water, and upward ejection of the kerosene by the steam. Eruption can also be accomplished by the vaporization pressure of the polluting layer itself. This method for separation of the liquids is economical, since it does not require vaporization of all of the liquid to be removed. Under the pulsed-laser beam we observed strong spattering of petroleum and kerosene to heights of 20—30 cm above the surface of the water (to which it returned in a fraction of a second) and settling of the spray on the mirror, lens, and screen; the energy consumed per unit mass of erupted liquid was much smaller than the energy required for vaporization.

Beam cleaning of liquid surfaces can be used not only

as a measure against pollution of the natural water surfaces of seas, rivers, and lakes, but also in applied and experimental physics. For example, vaporization and burnoff of surface pollutants can be used for purification of liquids in the laboratory. Local pulsed vaporization or burnoff of the film (which then flows in to fill the hole) can be used for bleaching, Q-switching, reflection modulation, light transmission, and many other purposes.

In addition to infrared laser radiation, powerful microwave electromagnetic radiation in the millimeter and submillimeter bands, which is absorbed in a thin layer at the surface of the water, can also be used for vaporization and burning off of surface layers.

[1] G. A. Askar'yan, E. K. Karlova, R. P. Petrov, and V. B. Studenov, ZhETF Pis. Red. 18, 665 (1973) [JETP Lett. 18, 389 (1973)].

V. M. Agranovich, B. N. Mavrin, and Kh. E. Sterin. Effects of Strong Anharmonicity of Phonons and Their Damping in Polariton Raman Scattering. Polaritons are usually understood to be electromagnetic-field quanta in dielectric crystals. In the language of the microscopic theory, polaritons arise as new elementary excitations of the medium when the interaction (mixing) of excitons or Born phonons with transverse photons is taken into account. For the long-wavelength range, however, the polariton dispersion law $\omega = \omega(k)$ can be found within the framework of macroscopic electrodynamics if the dielectric tensor $\epsilon_{ij}(\omega, k)$ of the medium is assumed known in some approximation. But if instead the dispersion law and the field amplitudes in the polariton are known, the inverse problem can be solved, i.e., the tensor $\epsilon_{ij}(\omega, k)$ can be reconstructed (see[1,2]). First-order Raman scattering of light (RSL) by polaritons in crystals without inversion centers (such crystals have a nonzero nonlinear polarizability tensor χ_{ijl}, which determines the intensity of the process), while enabling us at once to obtain the above information on the properties of the polaritons, can also be used to analyze effects of strong anhamonicity of the phonons, which results in some cases in the formation of states in which phonons are bound to one another (biphonons). For example, when a polariton branch crosses an energy band corresponding to the presence of two free optical (like or unlike) phonons in the crystal, the polariton spectrum is found to be highly sensitive to phonon anharmonicity. That is to say, if this anhamonicity is strong enough and the biphonon state is formed, a gap whose width is proportional to the phonon anharmonicity constant is formed in the polariton spectrum as a result of Fermi resonance even when damping is quite weak[3,4]. The existence of this gap has now been observed experimentally[5-7] (Fig. 1), an observation that is, in virtue of the above, an indirect proof of the formation of biphonon states in the cases studied in[5-7].

Dissipation of electromagnetic-field energy in the crystal broadens the lines of RSL by polaritons. A theory of RSL by polaritons with consideration of damping was first developed in[8], but in[9] and later in[10-12], a formula was obtained for the intensity of RSL by polaritons that is valid in a broader range of polariton fre-