

## REMOTE ANALYSIS OF THE ELEMENT COMPOSITION OF THE SEA WATER USING THE EMISSION SPECTRA OF THE PLASMA INDUCED BY LASER RADIATION

D.V. Vlasov, A.M. Prokhorov, D.Yu. Tsipenyuk, and V.S. Bukreev

*Institute of General Physics of the Academy of Sciences of the USSR, Moscow  
Received December 4, 1990*

*The paper presents some results of measurements of the emission spectra of the sea water breakdown induced by a Kr-F laser radiation. Spectral lines of the main elements being contained in the sea water can be distinctly seen in the spectra that makes it possible to determine the water salinity by laser radar technique.*

The remote laser sounding of the ocean is carried out with the use of airborne, shipborne, and spaceborne lidars for the investigation of the ocean.<sup>1,2</sup> An important problem is the determination of the salinity and the chemical composition of the sea water, which have not yet been practically solved by the laser radar technique. It is possible to determine the temperature and the salinity of water based on the Raman scattering line shape, but for the field conditions this method is difficult for realization. At the same time the method of determining the chemical composition of the atmosphere based on the record of the emission spectrum of the air breakdown induced by laser radiation is well known.<sup>3</sup> The development of the method and apparatus for the remote analysis of the element composition of the aerosol matter using the emission spectra of the laser spark results in a sounding range of 250 m and the average concentration sensitivity of the element analysis 0.1–10  $\mu\text{g}/\text{m}^3$  with relative error of the order of 30%.

In this paper we study the possibility of determination of the salinity and the chemical composition of sea water using the emission spectra laser spark induced in the sea water. The source of radiation was a Kr-F excimer laser (248.5 nm) with 60 mJ per pulse and a pulse repetition frequency 2 Hz. Laser radiation was directed normally to the water surface and focused with a quartz lens which has the 20 cm focal length. Sea water was enclosed in an open glass cell and was 10 cm deep. The radiation initiated by the laser breakdown was recorded at a small angle with the vertical to avoid the Fresnel reflection of laser beam incident on the detector. An OSA optical multichannel spectrum analyzer whose operational spectral wavelength range was 180–1000 nm was used as a detector, a diffraction grating of the spectrum analyzer had 150 lines/mm, the width of the receiving slit was equal to 30  $\mu\text{m}$ , and the interference filter was placed in front of the entrance slit to suppress the laser radiation approximately by a factor of  $10^4$ . The experiments were carried out with the solution of sea salt in the distilled water with the concentration close to natural one (about 50 g/l). Figure 1 shows one of the obtained emission spectrum. The laser radiation lines (near 248.5 nm), the Raman scattering lines in water (near 273.3 nm), the second order reflection from the diffraction grating of a polychromator (near 497 nm), which were used as the intrinsic reference lines for the calibration of spectra according to the wavelengths, can distinctly be seen in the spectrum. The lines caused by Raman scattering by oxygen (near 258.5 nm) and nitrogen (near 263 nm) can be seen near the laser line. Line spectrum is distinctly manifested against the background of the continuous spectrum of luminescence and glow of initiated plasma. We

subtracted nearly continuous emission spectrum of the laser spark in distilled water from the obtained spectrum to improve the spectral contrast. Difference spectrum obtained in such a way is presented in Fig. 1. The emission lines of Na, Cl, Mg, and Ca, i. e., the elements whose amounts are large in the sea water, can distinctly be seen in the spectra shown in Fig. 1. To identify the spectral lines, the well-known strong lines of the elements were used.<sup>4</sup> We have found in the experiments on laser breakdown in pure salt solutions that the strongest lines of the emission spectrum (near 394 and 383 nm) belong to Ca, Mg, and Ca. This allows one to determine the water salinity with high accuracy. The sections of the distilled water spectra with different sea salt concentrations are presented in Fig. 2 (ratio of mass concentrations is 1:3). To check qualitatively the potential capabilities of the method for salinity determination, the spectra are scaled to the amplitude of the signal of Raman scattering in the water. On account of the fact that the model experiments were performed under practically identical conditions, such a normalization is natural, though the careful testing is needed. It should be noted that when our experiments were finished we learned that analogous investigations were made in the wavelength range 550–800 nm with the source of radiation at 1.06  $\mu\text{m}$  (Ref. 6).

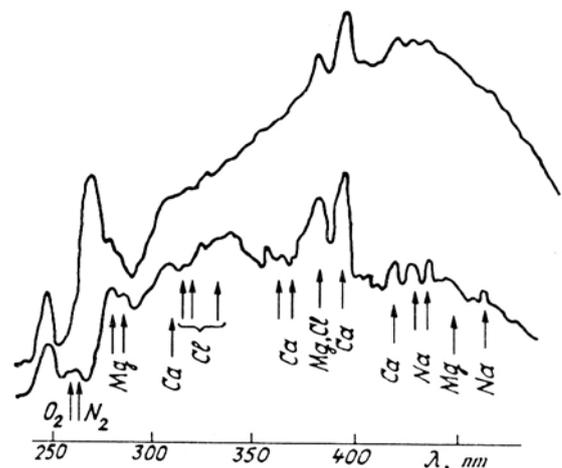


FIG. 1. The emission spectrum of the laser spark in sea salt dissolved in distilled water (mass concentration is 50 g/l) (upper curve); the same spectrum after subtraction of the spectrum obtained in distilled water (lower curve).

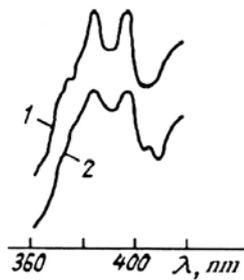


FIG. 2. The sections of the spectrum of the laser spark in the distilled water with different sea salt concentration. The salt concentration in the solution corresponding to spectrum 1 exceeds by a factor of 3 the salt concentration in the solution corresponding to spectrum 2.

Thus, the results of the first model experiments point out the prospects of application of the analysis of the emission spectra of the laser spark in sea water for the remote field measurements of the salinity and element composition of sea water. Undoubtedly, the improvement of the contrast of the spectrum can be achieved by the use of the two-pulse

excitation, as in the case of irradiating dielectrics and metals,<sup>5</sup> though in the formulation of the problem considered above other factors will be controlling.

We are very grateful S.K. Vartapetov and A.Z. Obidin for the appreciable assistance in performing the experiments.

#### REFERENCES

1. A.F. Bunkin, D.V. Vlasov, and D.M. Mirkamilov, *Physical Foundations of the Laser Aerosounding of the Earth's Surface* (FAN, Tashkent, 1987).
2. M.P. McCormick, in: *Abstracts of Papers at the Fifteenth ILRC*, Vol 2, Tomsk (1990).
3. I.V. Samokhvalov, Yu.D. Kopytin, I.I. Ippolitov, et al., *Laser Sounding of the Troposphere and Underlying Surface* (Nauka, Novosibirsk, 1987).
4. A.N. Zaiedel', V.K. Prokof'ev, S.M. Raiskii, et al, *Table of Spectral Lines* (Nauka, Moscow, 1977).
5. A.Yu. Bukharov and S.M. Pershin, *Zh. Prikl. Spektrosk.* **51**, No. 4, 564-571 (1989).
6. O.A. Bukin, A.N. Pavlov, N.V. Sushilov, et al., *Zh. Prikl. Spektrosk.* **52**, No. 5, 736-738 (1990).