

Laser sensor for airborne prospecting method of oil & gas deposits

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Remote laser spectroscopy availability for airborne search of the oil-and-gas deposits has been examined. Experiments were carried out under the CARS circuit. Minimal concentrations of heavy HG of 200 ppb are remotely measured in laboratory. As estimations have shown the reliability of heavy HG detection can exceed 80 % at the integration method of seismic prospecting and remote laser sensing in CARS circuit.

Our staff has developed a unique set of laser-optic components and the latest technology of UV high-precision and high-dispersion optics, has created and introduced series of compact solid-state lasers with diode pumping at various enterprises, and is using the latest achievements in the area of photodetector devices, baseline models, and automatic means of recording and processing signals in the gigahertz range of frequencies. The accumulated scientific and engineering reserves and practical experience in the development of laser information complexes have been the basis for developing and implementing a new technology for creating multifunctional lidars.

The small-sized prototype of onboard scanning Raman lidar as the gas analyzer have been manufactured and tested in real conditions of transcontinental gas pipeline. Minimal concentrations of methane outflow of 6 ppm and of hydrogen sulphide one of 2 ppm are remotely measured in natural flight conditions [1]. Now, our team creates a new generation of lidar system with improved characteristics for oil, gas exploration. We discuss some advances in equipment sensitivity for the techniques of remote laser spectroscopy and Raman lidar which sufficiently enlarge their applications. Our Raman lidar is an active, airborne laser remote sensing instrument with ultraspectral resolution ($\lambda/\Delta\lambda > 1000$) [2]. Unlike Raman spectroscopy, CARS employs multiple photons to address the molecular vibrations, and produces a signal in which the emitted waves are coherent with one another. As a result, the sensitivity of CARS is an orders of magnitude more than of spontaneous Raman spectroscopy.

Chamber filled by mixture of such hydrocarbon gases and air served as the simulator of hydrocarbon halo was irradiated by femtosecond Ti:Sapphire and nanosecond Nd:YAG lasers pulses. A pump beam of frequency ω_p (Ti:Sapphire, 800 nm, 30 fs, 0,2 mJ, 50Hz) and a probe beam at frequency ω_{pr} (Nd:YAG, 1064 nm, 8 ns, 60 mJ, 50 Hz) were focused in a

chamber. These beams interact with sample and generate a coherent optical signal at the anti-Stokes frequency ($\omega_{pr} + \omega_p - \omega_S$). The anti-Stokes signal ($\lambda = 656$ nm for CH₄ and $\lambda = 658$ nm for C₃H₈) is resonantly enhanced when the frequency difference between pump and Stokes beams ($\omega_p - \omega_S$) coincides with the frequency of Raman resonance, which is the basis of technique's intrinsic vibrational contrast mechanism. Spectra were registered with use of the USB2000 compact optical fiber spectrometer (Ocean Optics). Back scattering anti-Stokes radiation got on a spectrometer and received spectrum was further processed on PC. Pressure of methane and propane chosen as indicator substances of hydrocarbon deposits was made ~ 0.01 Torr in 0.2 m-length chamber that was corresponded to 10m-thickness of an real halo with concentration at level of $5 \cdot 10^{12}$ cm⁻³, i.e. 200 ppb, for each of these gases. Since Ti:Sapphire laser has a wide spectrum, the coherent anti-Stock scattering of radiation occurs from corresponding Fourier-components of pump ($\lambda = 800$ nm) and Stocks signal ($\lambda = 1064$ nm), removed on Stocks shift size of researched gases. Therefore it was possible to observe an occurrence of new components about 650 nm, various for different HHG, in anti-Stock scattering spectrum.

Method CARS allows to realize measurement of the concentration level of 3-10 molecules and determine hydrocarbons in real atmosphere with presence of impurities. As estimations have shown the reliability of HHG detection can exceed 80 % at the integration method of seismic prospecting and laser remote sensing in CARS circuit with the use of Nd:YAG laser (1064 nm, 3J, 6 ns, 300 Hz). CARS-Lidars based on ultraspectral devices are used for solving problems of ecology, for studying dangerous gases of technogenic origin that appear in the atmosphere when disposing of wastes, trash, poisonous and explosive substances, and for searching for the growth of narcotic plants. This is far from a complete list of the possible applications of such apparatus.

- [1] S. V. Alimov ; S. V. Kascheev ; D. V. Kosachev ; S. B. Petrov ; A. P. Zhevlakov «Multifunctional lidar for needs of oil-and-gas pipes» Proc. SPIE 6610, 66100B (2007).
- [2] S. Alimov, D. Kosachev, O. Danilov, A. Zhevlakov, S. Kashcheev, A. Mak, S. Petrov, and V. Ustugov, "Aviation Raman lidar with ultraspectral resolution," J. Opt. Technol. 76, 199-207 (2009)