Calibration of KA-14 LIDAR to Measure the Fluorescence Spectra of Oils Extracted in Various Zones

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Abstract

Laser sensing methods have been used since the 60s, and since the 90s this method has reached a new level along with the reduction in the cost of the element base, and the development of computer technology and software. Currently, the laser sensing method has been recognized as one of the most modern active methods of remote sensing of environment. KA-14 LIDAR (Light Detection and Ranging) developed at the National Academy of Aviation was successfully tested for the detection of oil pollution, and based on the analysis of fluorescence spectra of detected oil spills, distinctive features were observed between the spectra of oil samples extracted in the zones of the Absheron Peninsula. To create a database based on the spectra of various oil samples belonging to various Oil-Gas-Production Companies (OGPC), the KA-14 LIDAR calibration process was carried out, and the fluorescence spectra of the mentioned samples were measured using the calibrated KA-14 LIDAR. Author would like to note that the database based on these results can be used to determine the ownership of an identified oil leakage in the Absheron Peninsula.

Keywords: laser sensing, LIDAR, fluorescence, oil pollution.

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Müxtəlif zonalarda çıxarılan neftlərin flüoressensiya spektrlərinin ölçülməsi məqsədi ilə KA-14 LIDAR-ının kalibrovka edilməsi

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Xülasə

Lazer zondlama üsulları 60-cı illərdən başlayaraq istifadə olunmağa başlamış və 90-cı illərdən etibarən bu üsul element bazasının ucuzlaşması, hesablama texnikasının və proqram təminatının inkişafı ilə birlikdə yeni bir səviyyəyə yüksəldi. Hazırda lazer zondlama üsulu ətraf mühitin ən müasir aktiv məsafədən zondlanma üsullarından biridir. Milli Aviasiya Akademiyasında işlənib hazırlanmış KA-14 LIDAR-ı (Light Detection and Ranging) neft çirklənmələrinin aşkarlanmasında uğurla sınaqdan keçirilmiş və aşkarlanan neft sızıntılarının flüoressensiya spektrlərinin analizi əsasında Abşeron yarımadasının müxtəlif zonalarında çıxarılan neft nümunələrinin spektrləri arasında fərqləndirici xüsusiyyətlər müşahidə olunmuşdur. Müxtəlif NQÇİ-nə məxsus neft nümunələrinin spektrləri əsasında verilənlər bazasının yaradılması məqsədi ilə KA-14 LIDAR-nın kalibrovka prosesi həyata keçirilmiş və kalibrovka edilmiş KA-14 LIDAR-ı vasitəsi ilə sözü gedən nümunələrin flüoressensiya spektrləri ölçülmüşdür. Qeyd etmək istərdik ki, bu spektrlər əsasında yaradılacaq verilənlər bazası aşkarlanan neft sızıntılarının Abşeron yarımadasının hansı zonasına aid olmasının müəyyənləşdirilməsində istifadə edilə bilər.

Açar sözlər: lazer zondlama, LIDAR, flüoressensiya, neft çirklənmələri.

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Калибровка LIDAR KA-14 с целью измерения спектров флуоресценции нефти, добываемой в различных зонах

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Аннотация

В статье рассматривается метод лазерного зондирования – один из самых современных активных методов дистанционного зондирования окружающей среды. Разработанный в Национальной академии авиации KA-14 LIDAR (Light Detection and Ranging) был успешно испытан при обнаружении нефтяных загрязнений. На основе анализа спектров флуоресценции обнаруженных утечек нефти наблюдались отличительные особенности между спектрами образцов нефти, добываемой в различных зонах Апшеронского полуострова. С целью создания базы данных на основе спектров образцов нефти, принадлежащих различным нефтегазодобывающим компаниям, был проведен процесс калибровки KA-14 LIDAR, и с помощью устройства были измерены спектры флуоресценции отдельных образцов. База данных, которая будет создана на основе этих документов, может быть использована для определения того, к какой компании Апшеронского полуострова относится выявленная утечка нефти.

Ключевые слова: лазерное зондирование, LIDAR, флуоресценция, нефтяные загрязнения.

Introduction

Rapid and reliable detection of oil leaks on the water surface is one of the most important issues in terms of Environmental Protection in the coastal zones of the seas. KA-14 LIDAR, developed at the National Aviation Academy with the financial support of the State Oil Company of Azerbaijan Republic, has been successfully applied in the detection of oil spills occurring on the surface of the Caspian Sea and Absheron Peninsula. The working principle of KA-14 LIDAR is based on laser-induced fluorescence (LIF) of oil spots [1-5]. Crude oil is a very broad and diverse class of substances and complex compounds of hydrocarbons, salts, amines, sulfur compounds, and metals. It is known that the main components of crude oil include carbon (83-87%), hydrogen (11-14%), oxygen (up to 3%), nitrogen (0,1-2%), sulfur (0,05-6%) and microelements - metals (<0,1%; more common metals: iron, nickel, copper and vanadium) [6-7]. The basis of fluorescence spectroscopy applied for oil measurement and identification its aromatic compounds and their derivatives, which are the source of fluorescence of oil. 25 – 75% of the total carbohydrate content of the oil is made up of aromatic carbohydrates, the main of which consists of dual compounds. These compounds consist of benzene, naphthalene, anthracene, phenanthrene, fluoranthene, benzpirole, and other polycyclic aromatic carbohydrates and their derivatives, as well as porphyrins, which form heavy metals. Fluorescence irradiation of crude oils depends on its chemical composition, the concentration of fluorophore, and physicochemical properties of the oil. The fluorescence spectrum has wavelengths greater than 260 nm, encompassing the ultraviolet and visible range of light, and is more noticeable in the spectral range of 270-500 nm [8-10].

Currently, there are 8 OGPC and 4 Joint ventures located in different zones of Absheron peninsula in the Republic of Azerbaijan. The calibration process of KA-14 LIDAR and spectra of some samples were presented in the presented work to measure the fluorescence spectra of the oil samples obtained at the different Oil-Gas Production Companies.

Methodology

The calibration process of KA-14 LIDAR was carried out in the following sequence: Laser cooling system checked; The wavelength of the laser radiation (obtained from the Collimator and perceived by the telescope) was measured; Energy of laser pulses is measured;

Fluorescence spectra have been excited by the third harmonic's of the Nd: YAG laser (λ =355nm). Parameters of excitation: the diameter of the laser beam is d=5mm (after collimation); pulse frequency f = 20Hz; pulse duration is τ = 7ns.

As a reference in the measurements, oil stain artificially spilled on asphalt was taken and fluorescence spectra of oil stain were drawn by KA-14 LIDAR from different distances. In Figure 1, the results obtained from a distance of 50m and 120m are presented.

Spectra presented in Fig.1 were used from an average of 6 files, with 630 pulses in each.

Figure 2 presents separate integral spectra of oil, oil on asphalt, and asphalt. The spectrum of oil was obtained by the method of separation of the spectrum of oil on asphalt from the spectrum of oil on asphalt.

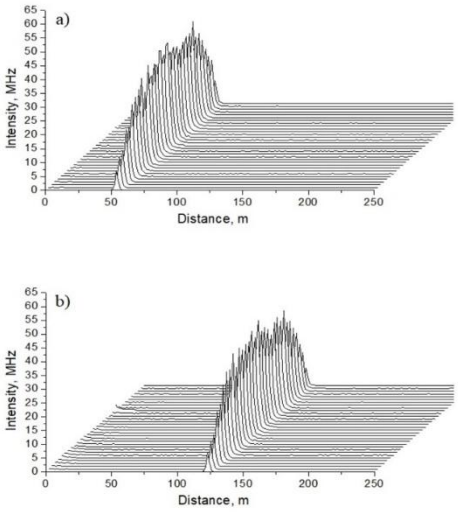

Figure 1 – Fluorescence spectra of oil stain sprinkled on asphalt from (spectra were detected by KA-14 LIDAR): a) 50m and b) 120m via KA-14 LIDAR

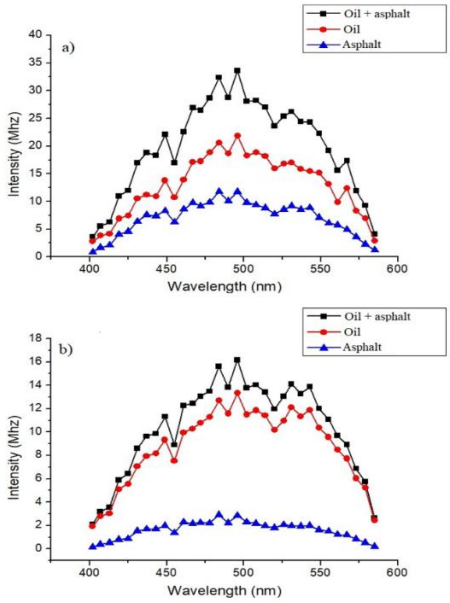

Figure 2 – Integral spectra of oil stain, oil and asphalt on asphalt a) 50m and b) 120m distance drawn

The experiment was carried out in the bright hours of the day on the territory of the National Aviation Academy. The energy of the laser was selected as E=10J and E=12J, respectively.

The results of the measurements made on the basis of calibration correspond to the results published in modern literature.

Results

At the next stage, the fluorescence spectra of 7 different samples of oil belonging to Absheron Peninsula were measured.

Measurements were carried out in laboratory conditions, using KA-14 LIDAR in the following sequence:

- Firstly, background measurements were made in the closed state of the laser output;
- Secondly, the fluorescence spectrum of crude oil was measured;
- Finally, the background spectrum was recorded with the removal of the given object from the fluorescence spectrum.

The signal input time was 120 sec for all measurements. In Figure 3, fluorescence spectra of oil samples belonging to 7 OGPCs located on the Absheron peninsula were investigated.

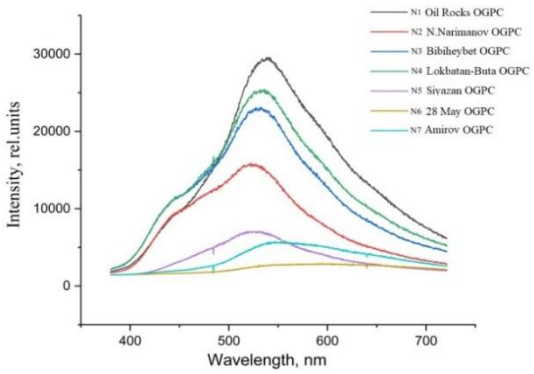

Figure 3 – Spectra of 7 different samples of crude oil belonging to SOCAR Oil-Gas Producing Companies by KA-14 LIDAR

The main differences between the fluorescence spectra of crude oil samples extracted from different zones are as follows:

- State of spectrum maximums of radiation;
- Presence of “shoulder” shaped bends on the sides of short and long waves;
- Width and shape of the irradiation strip.

Conclusion

The results of measuerements carried out by means of calibrated KA-14 LIDAR confirm that the LIF spectra of crude oil obtained in different zones of the Azerbaijan Republic are different.

The creation of the database based on this feature will allow determinaton of which one of OGPCs belongs this lekage. It should be noted that currently, work is underway to measure Raman spectra of crude oil samples and to include these spectra in the database.

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