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Effective, Conscious and Safe Laser Use in the Ramana StreetLab Mobile Spectrometer

Abstract

The StreetLab Mobile device manufactured by the Morpho Detection allows for quick and accurate identification of unknown substances. The spectrometer has been equipped with a remote service function. This ensures the identification of the substance in the hot zone from a safe distance, up to a maximum of 500 meters. Data from the device is transmitted wirelessly, which minimizes the exposure of rescuers to exposures with harmful substances. Using the Raman StreetLab Mobile Spectrometer to identify unknown chemicals during the rescue operations as well as during the exercises and training, the persons operating the device must be aware of the risks resulting from working on the presented device. The spectrometer contains a laser in its structure, which in the case of improper handling can be harmful to eyesight. Danger also threatens the user with flammable or explosive substances. The article presents the research in which the attention was paid to the effects that should be expected during the identification of hazardous substances by irresponsible people and not maintaining the principles of safe work with the device.

Keywords: mobile spectrometer, conscious use of laser, principles of safe use of the laser spectrometer

Skuteczne, świadome i bezpieczne wykorzystanie lasera w spektrometrze Ramana StreetLab Mobile

Abstrakt

Urządzenie StreetLab Mobile pozwala na szybką i dokładną identyfikację nieznanych substancji. Spektrometr został wyposażony w funkcję zdalnej obsługi, sięgającej maksymalnie 500 metrów. Dane z urządzenia transmitowane są bezprzewodowo, co pozwala ograniczyć do minimum narażenie ratowników na ekspozycje szkodliwymi substancjami. Wykorzystując spektrometr Ramana StreetLab Mobile do identyfikacji nieznanych substancji chemicznych, osoby obsługujące urządzenie muszą być świadome zagrożeń wynikających z pracy na urządzeniu. Spektrometr zawiera w swej budowie laser, który w przypadku niewłaściwej obsługi może być szkodliwy dla wzroku. Niebezpieczeństwo grozi też użytkownikowi w przypadku substancji łatwopalnych czy wybuchowych. W artykule przedstawiono badania, w których zwrócono uwagę na skutki, z jakimi należy się liczyć podczas identyfikacji substancji niebezpiecznych przez osoby nieodpowiedzialne i nie zachowujące zasad bezpiecznej pracy z urządzeniem.

Słowa kluczowe: mobilny spektrometr, świadome wykorzystanie lasera, zasady bezpiecznego korzystania ze spektrometru laserowego

Introduction

The effectiveness of the StreetLab Mobile spectrometer can be demonstrated by a wide range of identified substances, such as toxic industrial materials, explosives, toxic industrial chemicals, chemical warfare agents, white powders, drugs and biological pathogens [11, 13]. The spectrometer samples the chemicals being in plastic, glass, transparent and even translucent packaging. It allows to analyze powders, pills, liquids and solids. Thanks to the fact that it does not require special sample preparation, it is fast and minimizes the possible human errors. The automatic calibration of the device ensures the high accuracy of the measurements. The spectrometer automatically records the test results, which allows you to avoid accidental deletion or modification of the received data [12, 14]. The operator has access to the internal library, which comes from the Environmental Protection Agency and contains a record of 10 060 hazardous substances. All tests were carried out in compliance with health and safety rules. The person performing the research was dressed in a lab coat, safety goggle and gloves for complete protection [2, 8].

Types of bands observed in the Raman spectrum

The Raman spectroscopy is based on measuring the scattering radiation, i.e. inelastic photon scattering. The particle symmetry determines which vibrations are active in the spectrum. This is expressed in the selection rule, which determines the probability of observing a given band. The occurring bands are as follows:

- Rayleigh band – formed as a result of the interaction of photons of radiation with a frequency of v_0, which do not match any energy levels of the molecule. However, when the molecule returns to the same energy level after interacting with the radiation, it is then the classic Rayleigh scattering.
- Stokes band – are formed when the molecule after interaction with the radiation will move to a higher level of oscillation, and the scattered photon has energy lower by the difference of the oscillatory levels hν. The name of this band is derived from the Stokes principle, which is valid in fluorescence.
- anti-Stokes band – they arise when the molecule was on an excited oscillatory level before the exposure to radiation. Then this impact will transfer it to the zero oscillatory level. As the name suggests, the anti-Stoke band can be seen in the Raman spectrum on the side opposite to the Stokes band in relation to the Rayleigh range. The anti-Stoke band usually has lower intensity than the stokes band [7, 9]. Raman bands are shown in the Fig. 1

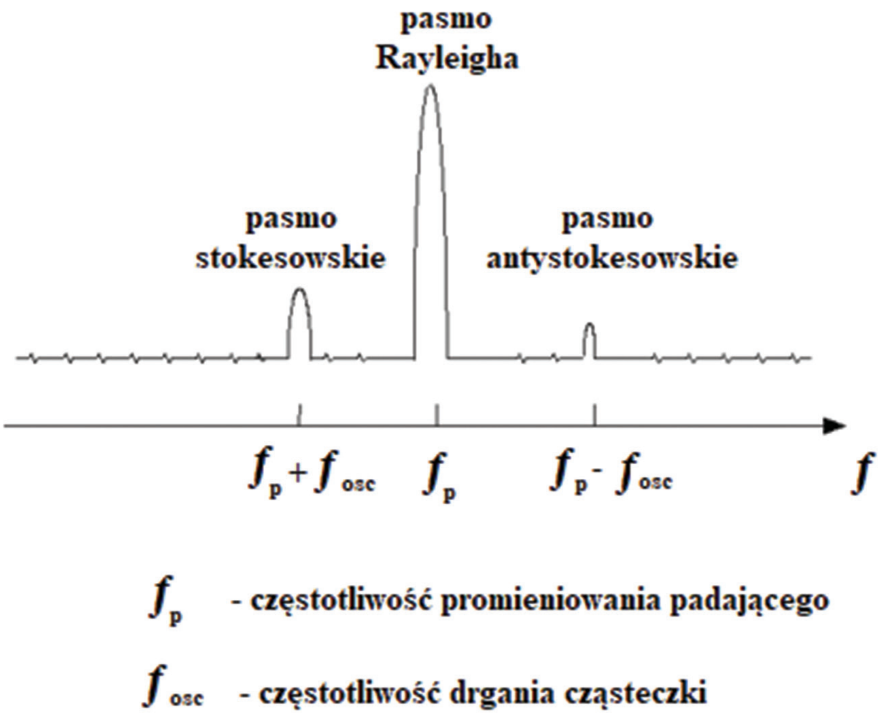

Fig. 1. Scheme of the Raman spectrum
Source: own elaboration based on [15]

Research methodology

All tests were carried out in compliance with the health and safety rules. The examiners were dressed in lab coats, safety goggles and gloves for complete protection [10].

Samples of methanol, acetone, ethyl acetate, phosphorus red and potassium chlorate, HMDT – hexamethylenetriperoxideamine – urotropin peroxide were tested. Particular attention was paid to the principles of safe use of the laser spectrometer.

Fig. 2 shows the StreetLab device.

Fig. 2. The way of making markings and the appearance of the device

Source: [6]

Substances tested

Methanol

Pure methanol is burned with a pale blue flame. One ml was taken for the study. The StreetLab Mobile device was set to the lowest laser power and the longest identification time [16]. Figures 3 and 4 show the spectrum of the sample and the spectrum of methanol from the device library. The results of the measurement were obtained at the level of 98% compliance.

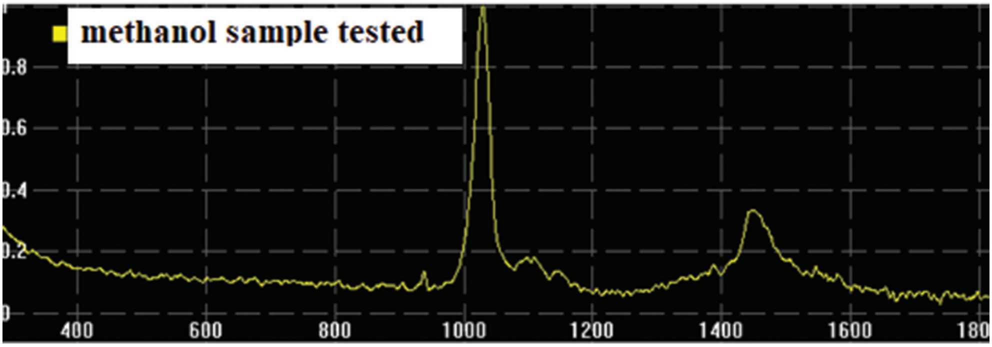

Fig. 3. The spectrum of the methanol sample tested

Source: own elaboration based on [6]

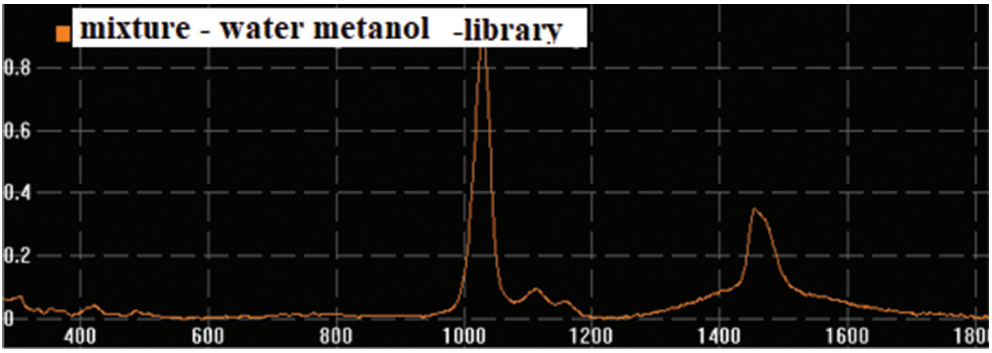

Fig. 4. The methanol spectrum from the StreetLab library

Source: own elaboration based on [6]

Acetone

C_3H_6O acetone is an organic chemical compound belonging to the group of ketones. The compound is a volatile, transparent liquid that mixes with water in all proportions and has a sharp, characteristic smell [1, 4]. In the study, the laser was set to the lowest power and the longest identification time. The obtained results were at the level of 99% compliance.

Figures 5 and 6 show the spectra of the sample and the spectrum of the acetone from the library.

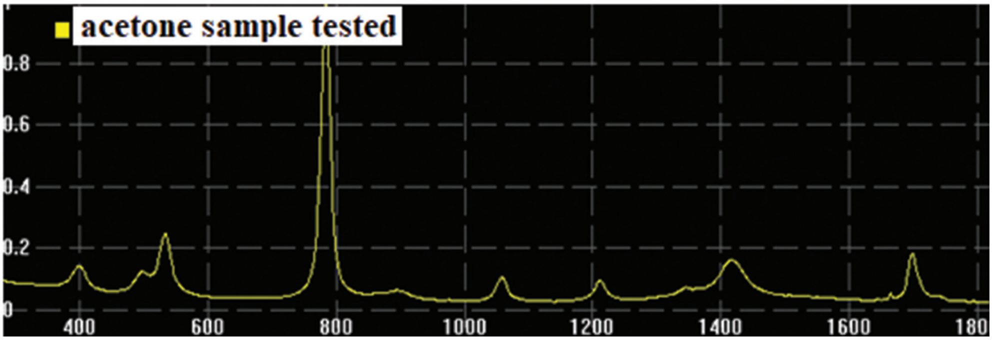

Fig. 5. The spectrum of the acetone sample tested

Source: own elaboration based on [6]

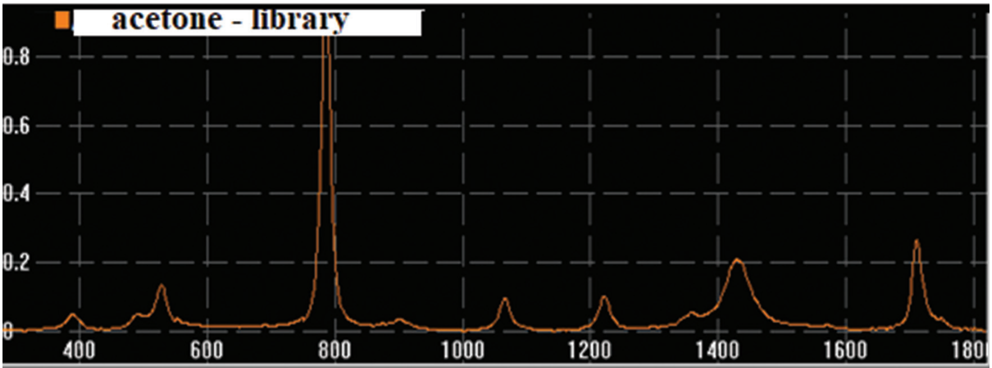

Fig. 6. The acetone display from the library

Source: own elaboration based on [6]

Ethyl acetate

Ethyl acetate is a chemical compound of the formula $C_4H_8O_2$. As in previous measurements, 1 ml of analyzed substance was tested. The spectrometer was set to the lowest laser power and the longest identification time. The result of the spectra adjustments was 97% for the ethyl acetate. Figures 7 and 8 show the spectrum of the sample and the spectrum of ethyl acetate registered in the library.

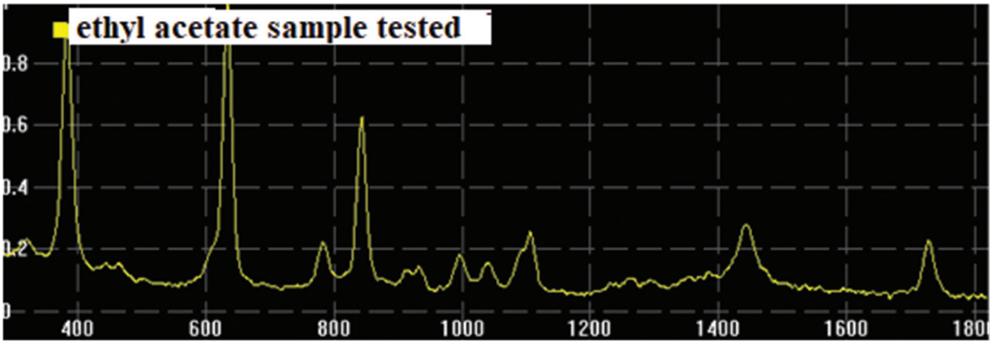

Fig. 7. the spectrum of the ethyl acetate sample tested

Source: own elaboration based on [6]

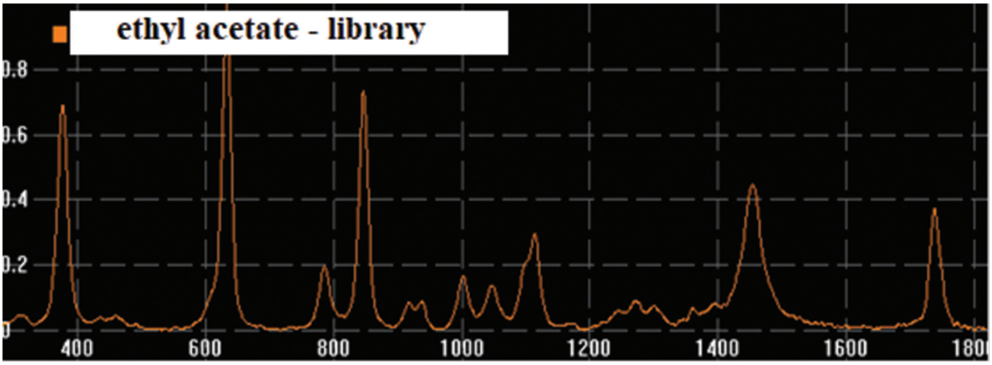

Fig. 8. The ethyl acetate display from the library

Source: own elaboration based on [6]

Gunpowder black

It consists of dust-milled ingredients in the proportions of 74.64% potassium nitrate, 13.51% wood charcoal, 11.85% sulfur [8]. 200 mg were collected for the study. Due to the fact that it is a substance that the laser emitted by the device could ignite, a cover made of the transparent polycarbonate was used. The laser power is set to the lowest. After positioning, the free sample ignition was observed – Fig. 9, and after 4 seconds a sudden burning of the whole sample – Fig. 10.

Because the ignition of the sample occurred very rapidly, the study at the highest laser power was not performed. However, such a study was done in water suspension – Fig. 11.

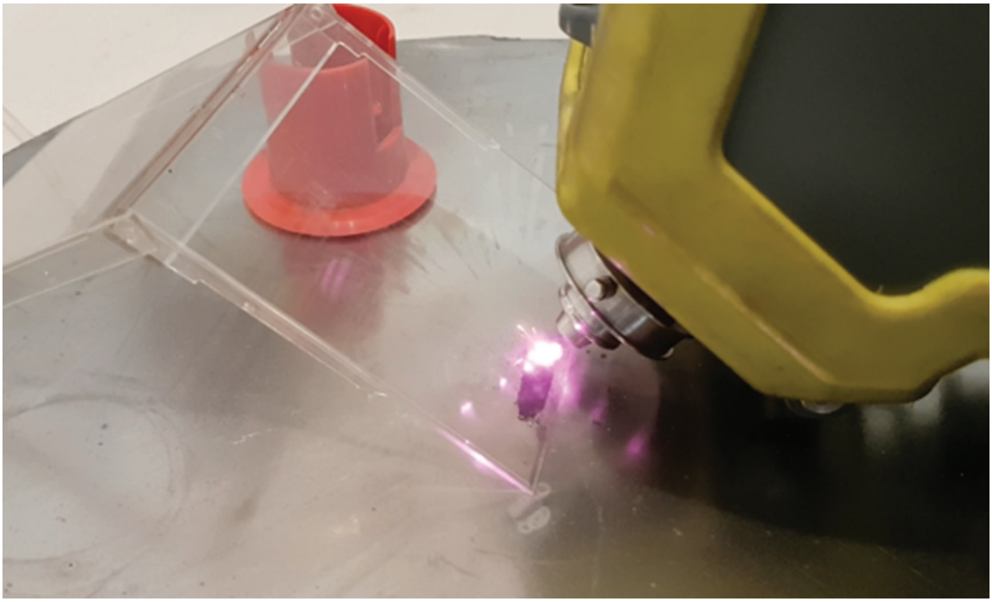

Fig. 9. Slow sample ignition

Source: [6]

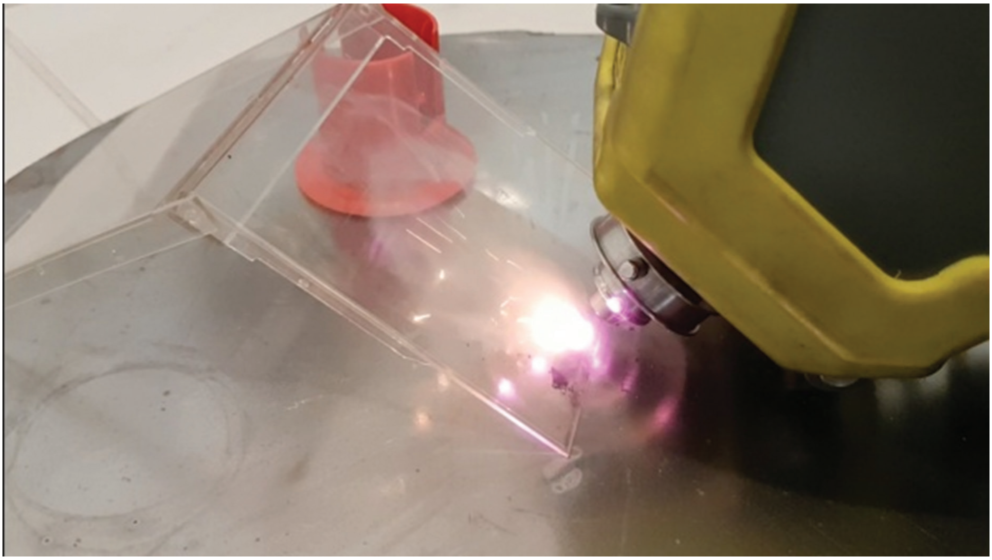

Fig. 10. Total sample burning

Source: [6]

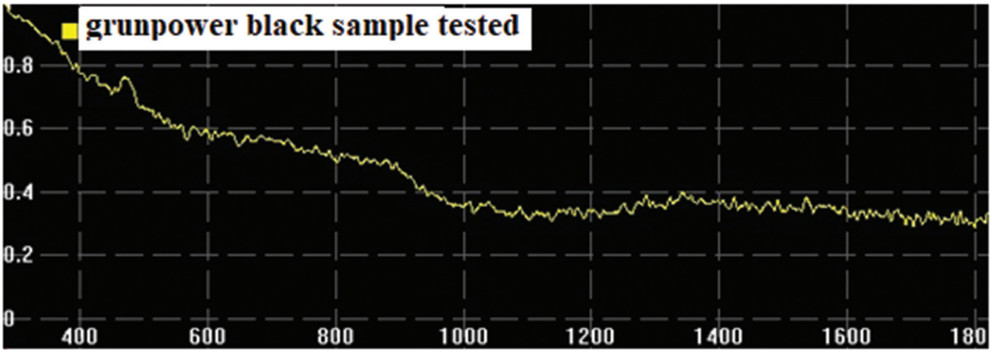

Fig. 11. The spectrum of the gunpowder black sample tested
Source: own elaboration based on [6]

The lack of identification was related to the presence of interference, which results from the fact that it is a mixture of three substances with a black color which is a limitation of the apparatus.

Chlorine powder

It is a variety of black powder where the potassium nitrate has been replaced here with potassium chlorate. The exact percentage composition is: 76.7% potassium chlorate, 11.6% sulfur, 11.6% wood charcoal [7]. 200 mg of chlorate powder, obtained by thorough mixing, 154 mg of potassium chlorate, 23 mg of sulfur and 23 mg of activated carbon were collected for the test. The dark gray mixture was tested with the additional cover of clear polycarbonate at the lowest laser power. After positioning, the laser ignited the sample after 2 seconds – Fig. 12. After another 3 seconds, the sample was completely burned – Fig. 13.

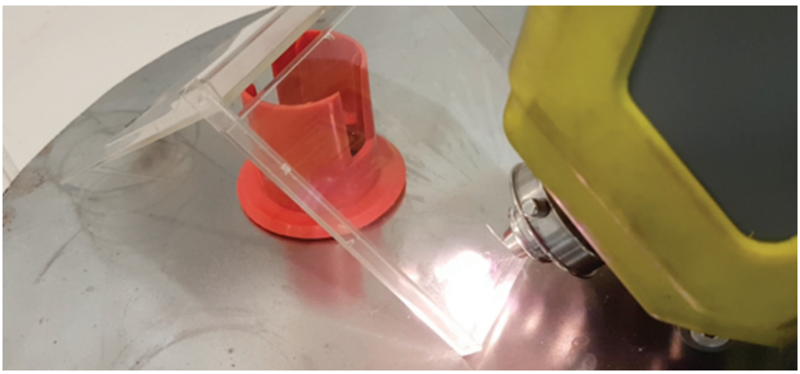

Fig. 12. Slow sample ignition
Source: [6]

Unfortunately, the spectrum test did not allow to identify the relationship. The only information obtained was that the examination of the chlorate powder in water suspension does not ignite the sample even at the highest laser power.

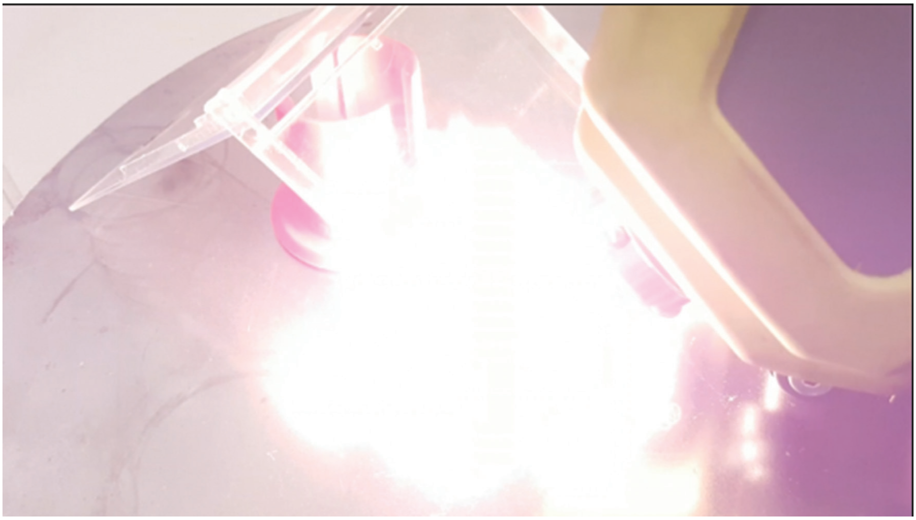

Fig. 13. Total sample burning
Source: [6]

Phosphorus red and potassium chlorate

A mixture of 10 mg of red phosphorus and 100 mg of potassium chlorate was collected for the study. The whole was mixed thoroughly until a homogeneous dark red color was obtained. During mixing, a special care was taken because in the case of these substances it is possible to initiate combustion at the very mixing [5]. The mixture prepared in this way was subjected to positioning with the lowest laser power set after covering this substance with a transparent polycarbonate – Fig. 14, and a moment later it was quickly burned– Fig. 15.

The combustion was accompanied by a large flare of light and the characteristic explosion such as for the pyrotechnical materials. The spectra from the obtained identification were not received. Due to such rapid ignition of the substance, even with the lowest laser power of further tests, no more power was introduced. On the other hand, the identification of this substance in the aqueous suspension was carried out, setting the highest laser power as a result of the analysis a spectrum was obtained – Fig. 16.

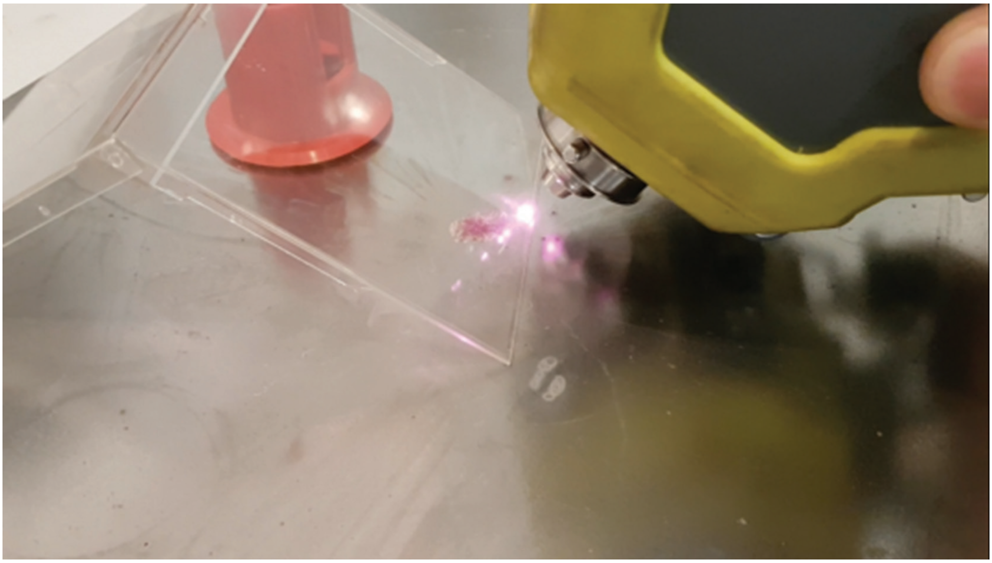

Fig. 14. Positioning

Source: [6]

Fig. 15. Rapid burning

Source: [6]

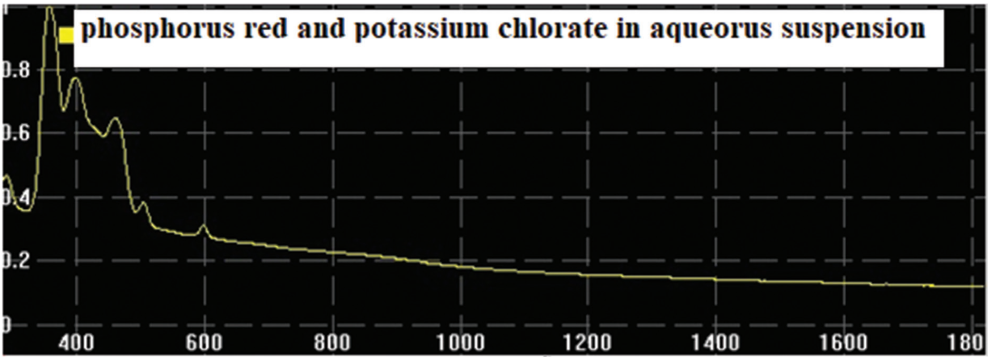

Fig. 16. The spectrum of the phosphorus red and potassium chlorate sample in an aqueous suspension

Source: own elaboration based on [6]

This spectrum is identical to the spectrum obtained as a result of analysis of the red phosphorus itself in an aqueous suspension. The reason for receiving the same spectrum is that the tested substance is a mixture of red phosphorus and potassium chlorate, which is very soluble in water and water-soluble substances are not identified by the StreetLab Mobile spectrometer due to its limitations. The substance during the analysis did not ignite as it was when identifying it as a powder. The use of water during the identification of this substance ensures safety during testing [2, 3].

HMTD

Hexamethylenetriperoxideamine, urotropin peroxide, is a chemical organic compound from the group of peroxides. It is strongly initiating explosive, sensitive to heat, flame, spark, strong shock and friction [4]. Therefore, the tests were carried out only in water suspension with the lowest laser power – figures 17 and 18.

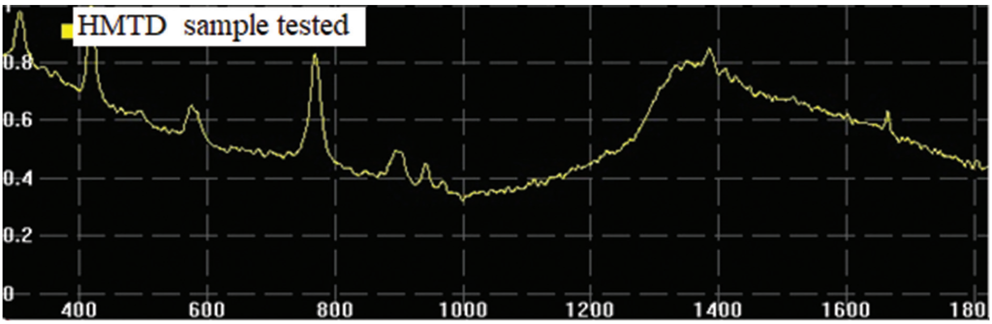

Fig. 17. The spectrum of the HMTD sample tested

Source: own elaboration based on [6]

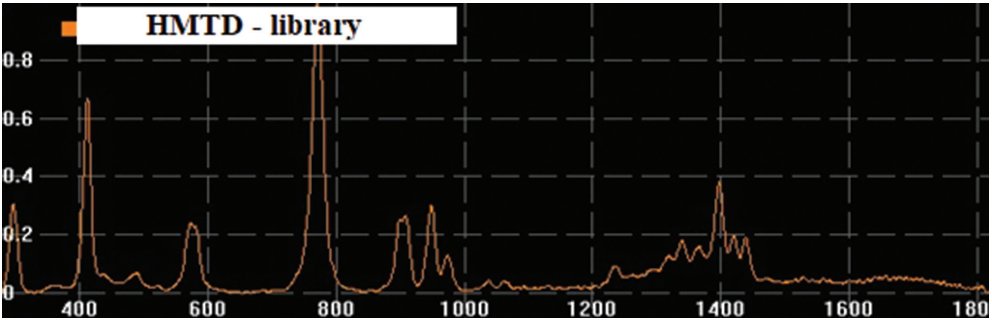

Fig. 18. Spectrum matched from the library

Source: own elaboration based on [6]

The obtained spectrum HMTD in 93% was matched to the spectrum from the library.

Summary and Conclusions

The Ramana StreetLab Mobile spectrometer is a simple and convenient to use and mobile device. It allows to identify a wide range of substances in maximum of 15 minutes. including sample preparation. Using it, the test results are obtained in the form of the spectrum of the tested substance together with the percentage adjustment of the obtained results to the library spectra. However, one should remember about the risks that may occur due to improper operation or ignorance of people who use it. Threats that may occur are damage to the eyes by a laser beam emitted and the possibility of ignition or explosion of the tested substance. The results of identification of various substances were presented, as well as hazards to be expected during their investigation, including black powder, red phosphorus or chlorate powder, which during the identification were ignited by the lowest laser beam emitted by the device. In addition, the substances that after contact with a fire or heat source explode, such as a mixture of red phosphorus with potassium chlorate or urotropin peroxide, have also been used in the study. The latter must be stored in a water suspension because drying it up can cause an explosion. In the tests carried out, it was also shown how placing the sample in water prevents its ignition or explosion and, consequently, ensures safety for the person carrying out the measurements. The obtained results of analysis of these substances in aqueous suspension in several cases did not allow to identify the tested substances. However, this results from the limitations of the device, i.e. difficult identification of substances with a dark color, the inability to identify substances that are mixtures of several different compounds, the inability to identify in a water suspension very well soluble substances in it.

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