

# Technical Solution of Device for Examination of Forensic Samples

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## **Abstract**

*Technical solution described in this paper enables non-destructive method of examination of forensic microtraces. The aim of an examination is to gain reliable description and examination of material properties of the samples. Examined samples are microtraces (paints, varnishes, inks, trichological material) and other material. One of the noted features is color of the sample. Color, as well as surface structure, forms one of the significant material property used in further examination and comparison of forensic samples. Implemented examination method is based on visual and spectroscopic measurement. Original device was designed to meet all the requirements and constraints given by the forensic method. Tests of the device were done to verify its abilities.*

## **Keywords**

*Forensic, integrating sphere, microtraces, colorimetry, spectroscopy, imaging, fiber, paint, criminal science*

## **1. Introduction**

Imaging and measuring of colors are fields of interest for many specializations. Color and material structure are significant features of matter. They can be used for further assessment, comparison and evaluation of examined samples. The idea of designing devices for colorimetric measurements is to improve efficiency of measurements with regard to keep the data reliable, compact, robust and reproducible. In this paper a design of such special device used for non-destructive examination of forensic samples is described. This instrument will be primarily used in forensic laboratories, staff of which also gave the impulse for creation of such instrument. Design of the device stems out of specific requests of respective users as well as from the state-of-the-art forensic methodology.

## **2. Methods of Measurement**

Modern trends in development of forensic science lead to implementation of highly precise and robust measuring techniques. Evidence material is usually compared to the reference material. Any conclusion is made out of all available data. Also there are many cases when no reference material is present. So not only comparison, but also whole sample examination has to be done.

Device described in this paper was designed mainly with respect to analyzed samples, so called microscopic evidence - paint coats, varnishes, hair, fibers, pigments, inks etc. Their main advantageous feature is their long-term stability. Samples of this kind can be successfully remeasured years after they were found. Their chemical content, color, appearance, or physical properties do not change apparently in course of time. But their featured disadvantage is their concentration. These samples are usually very small. Their size does not exceed millimeters, therefore some combination of macroscopic imaging and

a measurement method should be used. Furthermore, forensic science restricts usage of destructive methods in favor to the non-destructive ones. The reason is simple: there are two types of forensic samples – reference samples and evidence samples as was already mentioned above. Both of them are valuable, but the evidence samples are really rare. So the more tests a sample can survive unspoiled, the better confidence an investigator can get in examining evidence.

In general the device enables simultaneous visualization of examined samples and their spectroscopic measurement. The implemented method of examination is macro / microscopic observation and colorimetric measurements using spectral analysis is visible and UV light. So in the case of visual and spectroscopic measurement, the sample does not need any special preparation. It is simply fixed to a slide, transparent or black foil and measured.

The main aim of the design is to improve efficiency of colorimetric measurements with regard to keep the data reliable, compact, robust and reproducible.

### 3. Colorimetry

Color and material structure are significant features of matter. They can be used for further assessment, comparison and evaluation of examined samples. Since human color perceiving is highly subjective, some abstract mathematical models were created to describe the color.

Difficulties in using the mathematical color models are based mainly in the conversion algorithms between different color spaces. As a contrary to the spectral curves, color models describe only part of the visible spectrum – the gamut.

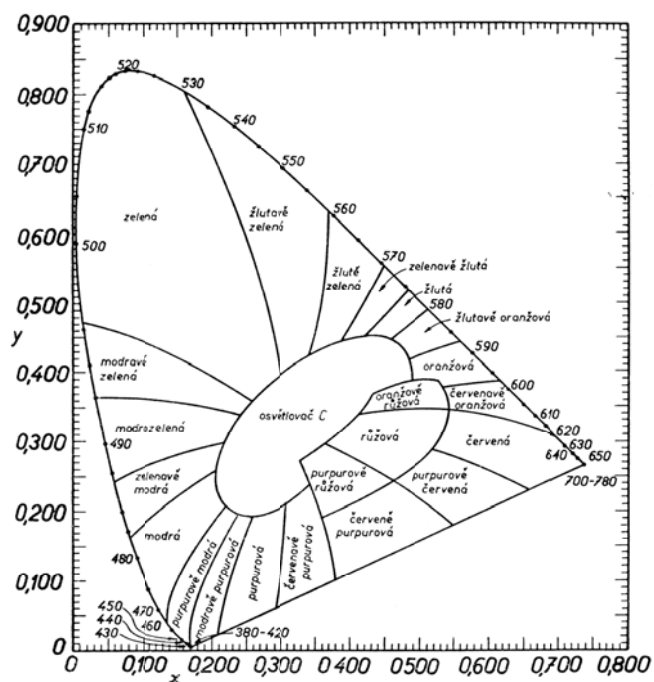
One of the first introduced color space was CIE, which describes any color using three parameters – tristimulus values (amounts of three primary colors in a three-component additive color model that match described color)  $Y$ ,  $x$  and  $y$ .

Graphical representation of the color space is on figure 1.

Another color model – RGB gamut is smaller than the gamut of a human eye. That is why there is not every RGB color equivalent for all combinations of pigments. But still it works sufficiently for comparison of color of the sample and some reference material.

I also have to briefly mention another mathematical color spaces like Munsell's; CMYK used in printing industry, or CIE derivatives – CIE Lab, Luv; RGB derivatives – HSI, HSL, and HSV which describes the colors the most similar way as human eye sees them.

The device uses a spectrometer to get spectral data which are further analyzed, measured and converted into some of the above mentioned color space to describe a color of the sample. These data are used to compare or search for a reference material in the investigation process.

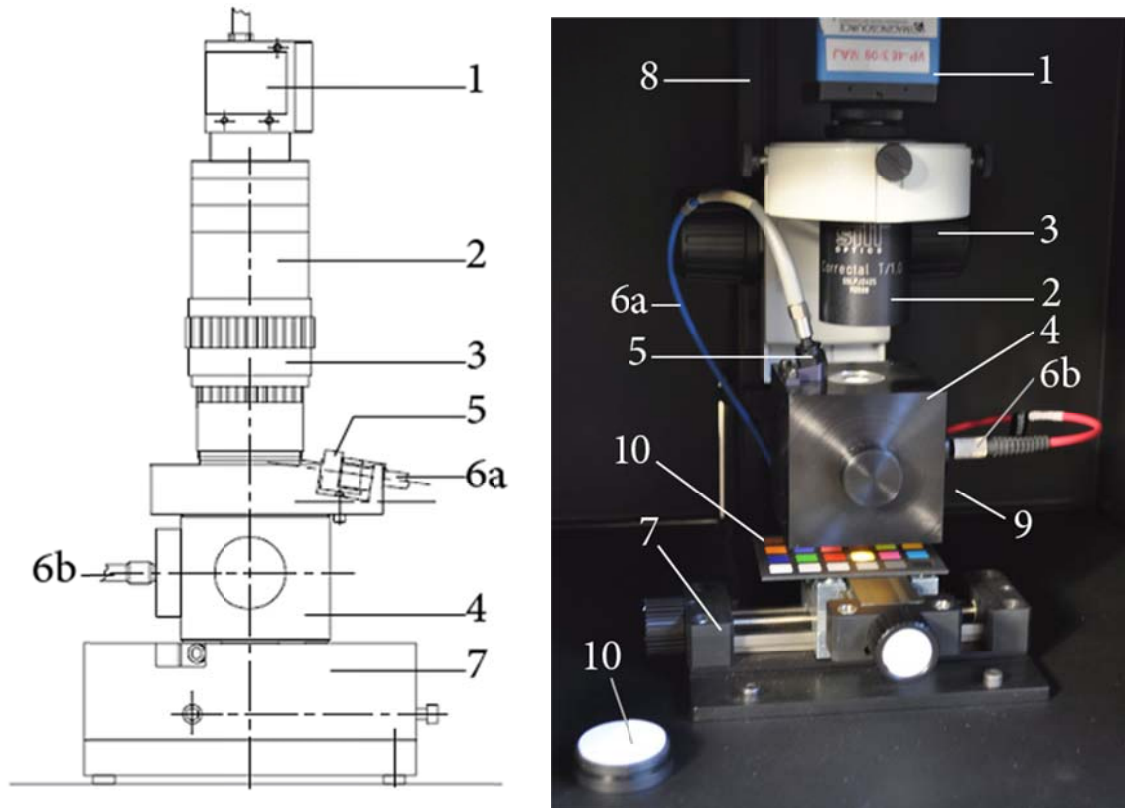


Obr. 7.17. Křivka spektrálních barev.

Fig. 1. CIE gamut, reference [7]

#### 4. Technical Solution

Draft and the resulting device can be seen on fig. 2.



**Fig. 2.** View of the whole device (left – a draft, right – the device)

1 – camera

2 – macrolens

3 – focuser

4 – integrating sphere

5 – collimating lens

6a – illumination light guide

6b – spectrometer light guide

7 – stage

8 – stand

9 – cover

10 – calibration standards

There are three functional groups in the design – illumination (positions 5, 6a on figure 2. and an illumination lamp – not displayed on the figure), imaging (positions 1, 2, 3 and 6b on figure 2. and a spectrometer – not displayed on the figure) and support (8, 9 on figure 2.). All function groups link up around the key component – the integrating sphere.

#### 4.1 Integrating Sphere

An integrating sphere (position 4 on figure 2. and figure 3) is an optical component which provides environment for gaining reproducible data. It can be also used as a light collector. Principally it integrates the reflected light using the inner sphere cavity and therefore homogenizes the data. This is very useful when glossy samples are measured.

The inner sphere is highly diffusive Lambertian surface. Material for this surface is solid polytetrafluorethylene PF4, sold as Spectralon®. Measured reflectance of this material varies between 95 - 99 % according to wavelength of the incident light. This material is easily machinable.

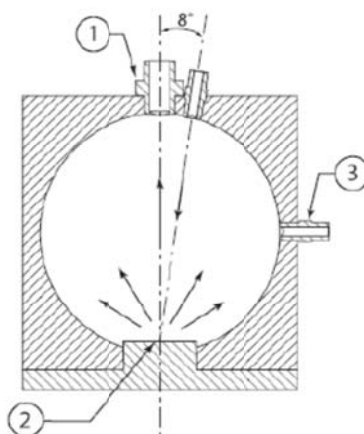
Besides also BaSO<sub>4</sub> (for UV to IR light range), gold (IR range), or TiO<sub>2</sub> can be used. These materials have different reflectance values.

Incident light beam enters the sphere through the aperture tilted by the 8° angle from the optical axis of the imaging system. The configuration and parameters of the device enables colorimetric measurements according to CIE 2004a standard. While the geometric conditions of the integrating sphere are defined as the 8°: d configuration, where the number means the angle of incident light and *d* stands for integrating sphere. Negative influences of polarization and directivity of incident light are eliminated. To avoid possible direct reflections from a glossy surface entering the spectrometer output aperture, a light trap is used. A light trap – a barrier, is placed near the sample aperture to absorb all direct reflections.

The integrating sphere that is used in the device was manufactured by Labsphere Inc. Diameter of its inner cavity are two inches. It has four opening ports. Three ports are used to mount components of the functional groups, while the fourth one remains idle and is covered with a cap with reflective film.



*Fig. 3. The integrating sphere*



*Fig. 4. Scheme of the integrating sphere, where 1 - camera with lens and illumination; 2 – sample; 3 - output to spectrometer*

### 3.2 Imaging and Illumination System

The samples are illuminated with a halogen illuminator using a light guide (position 6a on figure 2.). A collimator is mounted to the output aperture of the light guide to form uniformly illuminated spot (see fig. 5.). Depending on the diameter of used light guide and type of collimating lens, the gained spot diameter varies between 0.5 to 15 mm<sup>2</sup>. Size of the spot can be changed according to size of measured specimen.

Visible light is selected on purpose to match the spectral data to some color perceivable by a human eye. This is important because the information we get from the measurement can be used to clearly describe color of sought after clothing, tool, or car. When we need to detect possible traces of blood present



*Fig. 5. Collimating lens mounted to a light guide*

on the sample we should exceed the light range to the UV wavelengths. But in most cases, the spectral data are acquired from a spectrometer with spectral range usually from 380 to 750 nm.

The holder of the collimating lens is tilted under  $8^\circ$  to meet the CIE 2004a standard demands. Images are captured using an optical system which consists of macrolens (position 2 on figure 2.) mounted to a focuser (position 3 on figure 2.) and a color CMOS camera (position 1 on figure 2.). Zooming of the imaging system is done using the connected focuser. The image is transmitted simultaneously to a computer and can be digitally processed using the LUCIA Forensic software by Laboratory Imaging.

### 3.2 Spectrometer

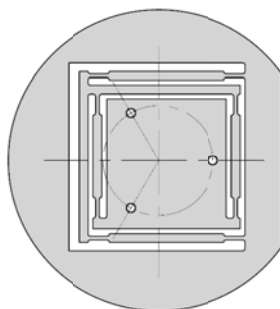
A spectrometer is connected via another light guide to the  $45^\circ$  port in the integrating sphere. The light guide is fixed so attenuation in the fiber is minimized.

The device can be calibrated using colorimetric reflectance standards (position 10 on fig. 2). All the samples described in chapter 4 were measured with the Avantes spectrometer AvaSpec 2048.

### 3.3 Stage and Stand

Sample is placed on a slide or foil on a stage (position 7 on figure 2.). The stage is located by the sample opening port (position 2 on figure 4).

While moving the sample is necessary to get the best results, a movable stage was designed. A compound table was used at first (as can be seen on figure 2), but backlash in its slide system decreased significantly precision of the navigation. So a movable stage for carrying a specimen is solved using flexural hinges (see figure 6). Such component enables precise moves in X and Y axis. The hinge is a mechanism free from backlash and works without any friction and has well-defined rotation axes. Its only disadvantage is the directive force but due to the construction, this force has no negative effect. Deflection of the stage in both axes is caused by two micrometer screws. In the future they can be replaced by actuators and stage movements can be automated and controlled by the computer.

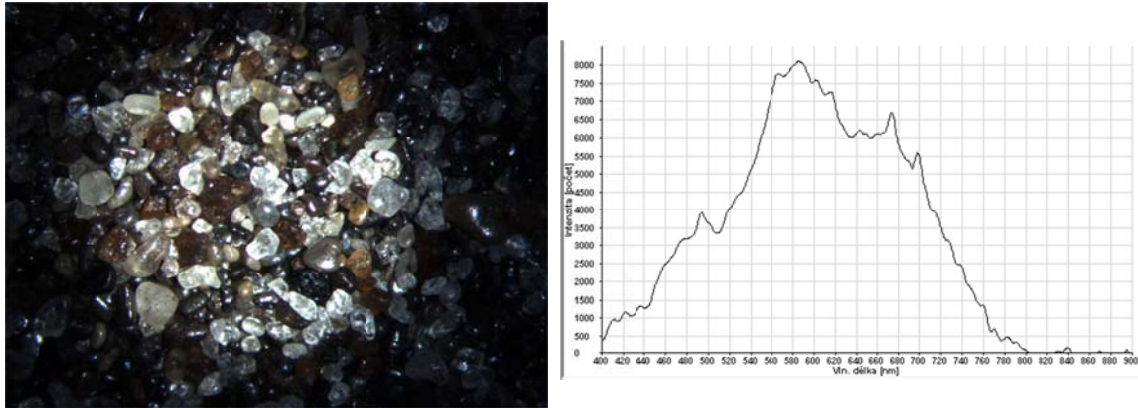


*Fig. 6. Flexural hinge used as an XY stage*

The last but not least component is the stand (position 8 on figure 2.) and the light-tight cover (position 9 on figure 2.) which works as a dark chamber. The cover is made of eloxed aluminium. It helps to minimize stray light entering or reflecting inside the device uncontrollably. Furthermore it protects the inner environment and gives stability to the whole device. The stand is the “spine” of the device. The integrating sphere and the camera system are mounted to it. This configuration enables free aligning possibilities with respect to high of measured samples.

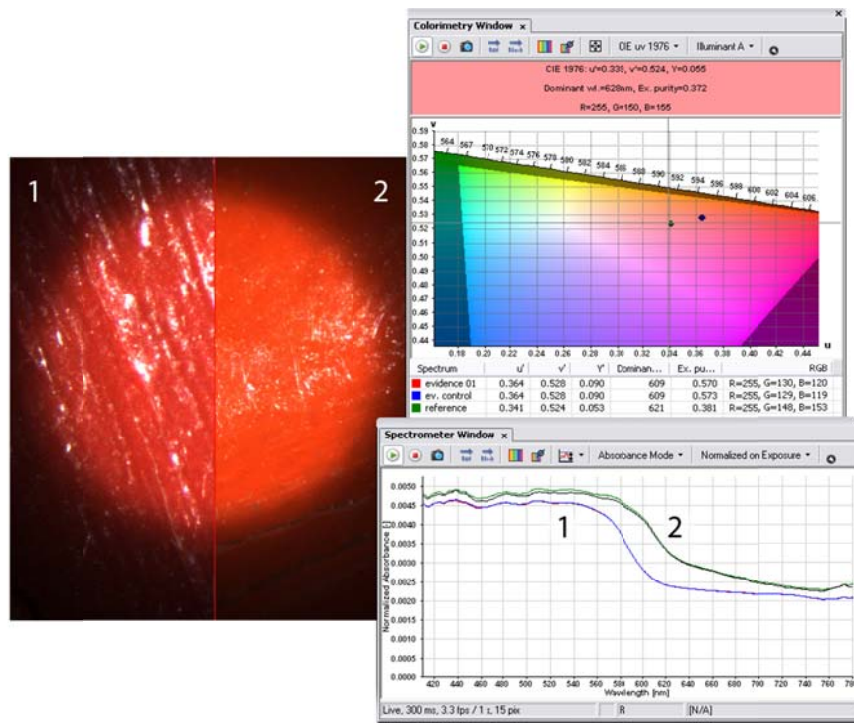
#### 4. Testing and Results

After the device has been manufactured and assembled, function test were carried out. Specific samples were picked out to test behavior and imaging features of the device. Specimen of sea shore sand with minor traces of radioactive elements is captured on figure 7 – left, and its spectrum on figure 7 – right.



*Fig. 7. Example of measured data, sample: sea shore sand*

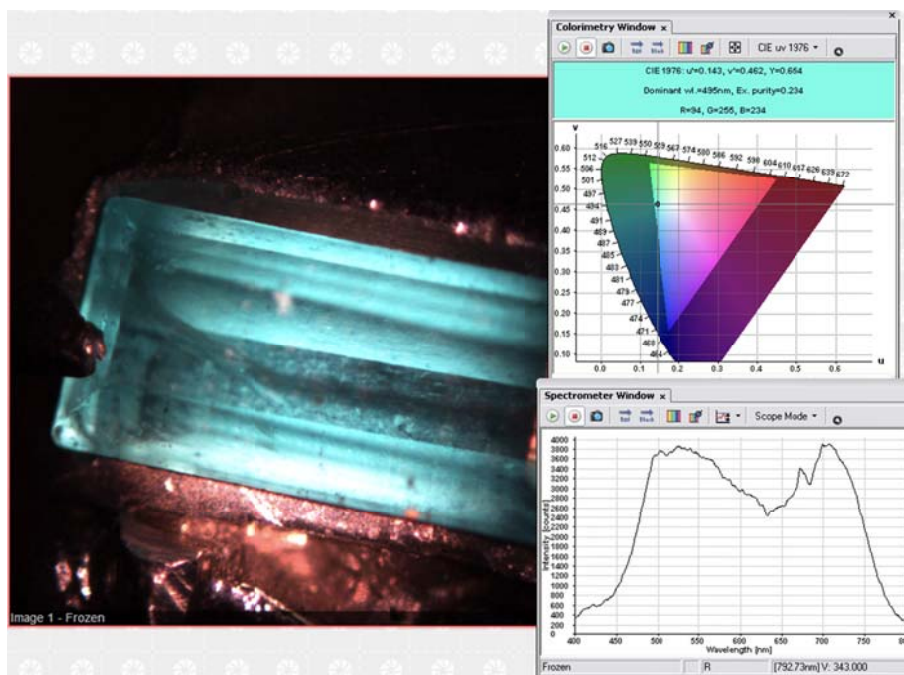
The field of view of a camera displays maximally a rectangle with longer site sized around 5 mm, which has been proved as sufficient for all examined samples. The colorimetry measurement was tested next. Two similar, but not identical paints obtained from two different pencils were measured and compared. The results are displayed on figure 8. Spectroscopic and colorimetric measurements have proved that they are not identical. Visual examination supplemented the results with image documentation of the comparison.



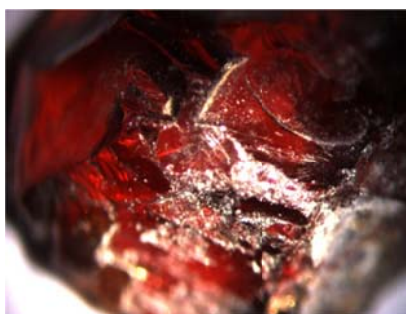
*Fig. 8. Comparison of measured data, sample: two different paints*



I have also tried to examine other than forensic materials. I have examined samples of gems. Results of two samples are displayed on figures 9 and 10.



*Fig. 9. Sample: gem - green blue emerald*



*Fig. 10. Sample: gem – garnet*

Results of all tests were satisfactory. Test demonstrated the ability of the device to meet all requirements with sufficient precision and reliability.

## 5. Conclusion and Acknowledgement

The device has already been built as a prototype and tested with generous support of Laboratory Imaging, s.r.o. The main benefit of this device is improvement of comparative examinations of samples. Evaluation of color and other material properties provide more complex and stable background for further forensic investigation. Also in addition to forensic samples, other materials like gems and minerals were successfully examined. This opens possibilities to use this device not only in forensic or gemological laboratories in other industry branches as well.

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