# Analysis of Laser and Inkjet Prints Using Spectroscopic Methods for Forensic Identification of Questioned Documents

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***Abstract:*** *The spectral properties in UV-VIS-NIR and IR regions of laser and inkjet prints were studied for the purposes of forensic analysis of documents. The procedures of measurements and processing of spectra of printed documents using fibre optics reflectance spectroscopy in UV-VIS and NIR region, FTIR-ATR with diamond/ZnSe and germanium crystals were optimized.*

*It was found that the shapes of spectra of various black laser jet prints and inkjet prints generally differ in the spectral regions UV-VIS-NIR and IR. However, the resolution of individual spectra, and hence of individual printers, based on the simple visual comparison is not reliable enough. However, using of these spectra for identification of individual printers should be enhanced by computational chemometric methods*

***Keywords:*** *document, spectroscopy, laser, inkjet*

## Introduction

In the realm of interesting facts frequently cited, a major legal step with strong implications for Questioned Documents examination was taken in 1562 when the English Parliament decreed forgery as a statutory offense. The damages incurred by forgery were considered so severe that in 1634 it was made a capital offense, which it remained for more than two hundred years. Thus, the crime of forgery was established in the sixteenth century, and in 1684 it was ruled that "comparison of hands is without doubt good evidence in cases of treason" (R v. Hayes, 10 State Tr. 307) [1].

The protecting copyright and verifying authenticity is very important in each aspects of our life. The documents like agreements, wills, and ownership of properties, judicial papers, and educational certificates or other commonly used documents in economy and society are used every day. Document is any material that contains printed information conveying some meaning or a message [2]. With the growing of new technologies creation documents increased too. However, the exchange principle, now called Contact Traces, first articulated by Edmond Locard in 1910 give us an advantage in this direction: "One cannot come into contact with an environment without changing it in some way"

The graphic documents represent a complex system of underlay and material structure of own graphical information (inks, toners, colours…) and substrate (usually paper) with mutual complex interactions of components, which are represented on document properties. Observation of authenticity and other characteristics of graphical documents are approached to from several directions. A basic process is material analysis of documents, i.e. determination of material characteristics of documents components, underlays and inks and layers structure in the case of multi-layered documents, which can help to investigate and clarify the facts. In practice throughout range of physical and chemical methods is used to the study and analysis of document composition and to state of graphical documents too. Currently used analytical techniques for investigation of inks and writing means pastes (TLC, HPTLC, GC-MS, and HPLC) [2-4] requires pre-treatment of a sample – separation of analysed material from carrier (mostly paper). This approach brings several disadvantages – risk of changes of chemical structure during separation of dyes, poor solubility of some components of writing materials in extraction reagent, irreversible damage of integrity of the studied material.

Due to the character of studied objects, the methods, which allow the greatest extend of non-destructive and micro-destructive investigation have special importance, among which molecular spectroscopy methods and other optical methods (colorimetric to objective dye description, photography and micro-photography in different spectral areas, imaging photometry and image analysis) are preferably used [5-9]. Various applications of spectroscopic methods in analysis of inks [5, 8, 10], dating of inks of balltip pens [11, 12], analysis of paper [11, 12], tonners for copiers and laser printers [13, 14], as well as forensic analysis of other materials [15] were described in the literature.

The aim of this work was study of spectral properties of laser and inkjet prints and assessment of possibilities of non-destructive methods of molecular spectroscopy to identify laser toners and inkjet inks.

## Experimental methods

Samples of prints were preparing as follows:

A model target (Figure 1), which consists of solid surfaces, lines corresponding to the thickness of the font size 8, 10 and 12 points and characters of size 8, 10 and 12 points was designed.

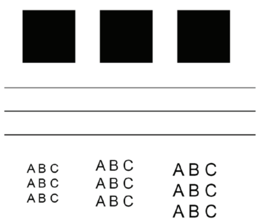


*Figure 1: Model target*

Subsequently a set of prints from various types of inkjet and laser printers, using the same type of office paper for all types of printers, with standard print quality settings were prepared.

For inkjet prints only the printing in black was selected.

For laser printers samples with black printing settings were printed and for color laser printers the samples with CMYK printing settings were printed, too..

Number of samples analysed: 15 prints of different inks for inkjet prints and 20 prints of different toners for laser prints.

## Methodology of work and examination methods

### *UV-VIS-NIR spectroscopy*

The reflectance spectra of inkjet prints in UV-VIS-NIR region area were measured on fibre optic reflectance spectroscopic system Ocean Optics, which consisting of HR 4000 spectrometer, UV-VIS-NIR light source DH-2000-BAL and of standard adapter for measurement of reflection spectra with geometry 45/45. For each measurement, the detector was calibrated on the blank paper near to the inked area. In this way, influences of the paper were largely excluded. A measured reflectance spectra R(l) were converted to optical density spectra D(l) (1).

$$D(\lambda) = \log 1/R(\lambda) \qquad (1)$$

Directly obtained spectra contain a lot of points and are noisy and almost unusable without processing (Figure 2a).

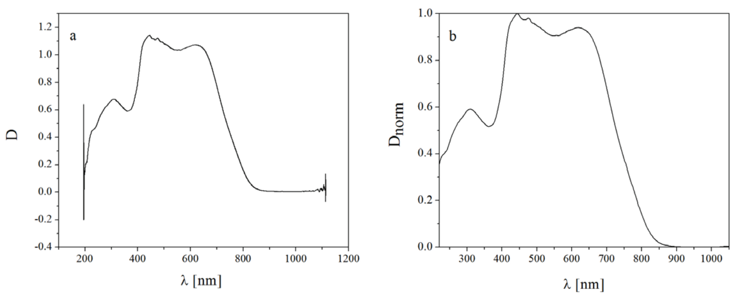


*Figure 2: a: Raw UV-VIS-NIR reflectance spectrum of inkjet print,*
*b: Final normalized UV-VIS-NIR spectrum of inkjet print*

The original spectra were interpolated in the wavelength range 220–1050 nm with the step 2 nm. Then the spectra were smoothed, without significant influence on the shape using Savitzky-Golay type of filter with filtration parameters 15 points and second polynomial order. Finally, the spectra of optical densities were normalized to interval 0–1. This type of shape enhancement is more suitable for analysis. Thus obtained spectra are appropriate for further analysis (Figure 2b).

***FTIR-ATR spectroscopy***

The reflectance spectra of laser prints in the Infrared region (IR) were measured on Excalibur FTS 3000MX (Digilab, USA) spectrometer with ATR adapter with diamond crystal. The obtained spectra of laser prints were processed and normalized in the same way as in the case of UV-VIS-NIR spectra of inkjet print above.

The reflectance spectra of inkjet prints in IR region are practically useless, because absorption signals of inks penetrated deeply into the paper are overlapped by strong absorption signal of cellulose.

## Results and discussion

***Laser prints***

FTIR spectra of 2 groups of laser prints are on Figure 3. Spectra are included into individual groups according to the different absorption in the wavelength range 1500–600 $cm^{-1}$. IR spectra of individual laser prints are generally different. Simple visual distinction is not unambiguous and for assignment of spectra to individual prints will the numerical, chemometric have to be used.

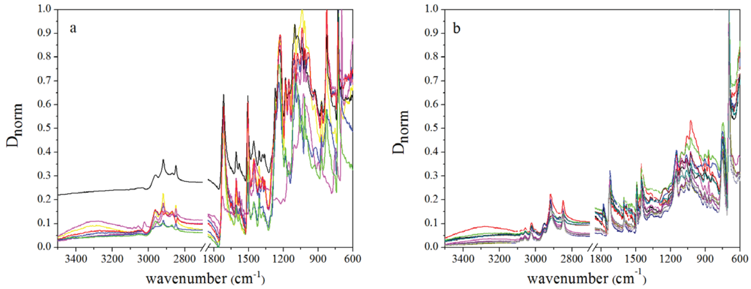


*Figure 3: FTIR spectra of 2 groups of laser prints*

On Figure 4 are spectra of laser prints of several producers. IR spectra of diverse laser toners are different in various extents. The differences between the spectra of laser prints of different producers are more significant (Fig. 5).

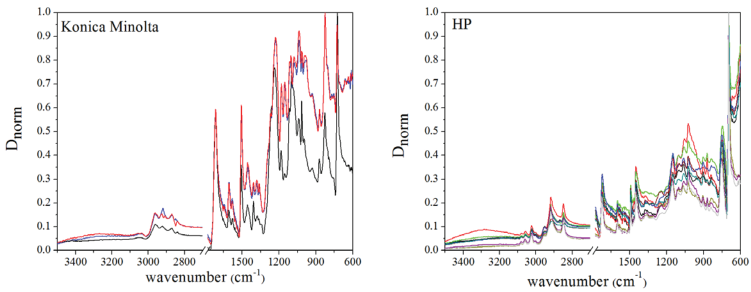


*Figure 4: FTIR spectra of laser prints of various producers*

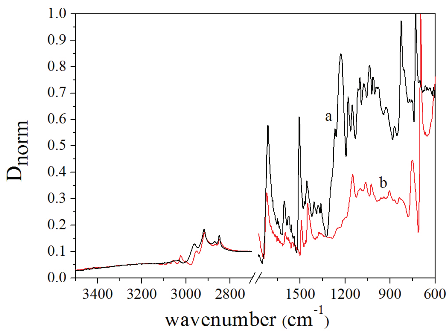


*Figure 5: Comparison of FTIR spectra of laser prints of different producers a: Nashuatec, b: HP*

### *Inkjet prints*

Comparison of normalised optical densities spectra (Figure 6) from 4 different types of prints shows, that the shapes of spectra of inks of Epson printers significantly differ from the shapes of spectra of Canon inks. The differences are most noticeable in the spectral range 600-1050 nm. Based on these differences of shapes the possibility of resolution of individual marks of inks can be presumed.

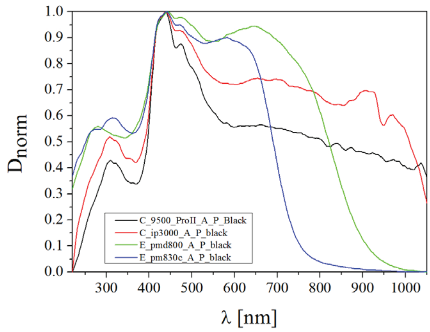


*Figure 6: Spectra from 4 different types of prints*

The spectra of two black inks of Epson used in different types of inkjet printers are on the Figure 7a. There is significant bathochromic shift into the near infrared region in the spectrum of ink from the printer Epson PM-D800, so spectra of these two inks can be resolved.

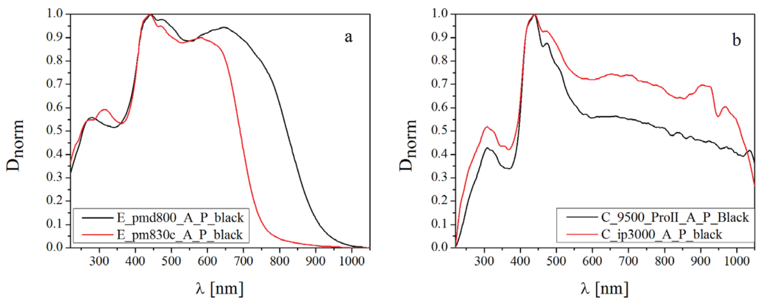


*Figure 7: Spectra of black inks of different Epson inkjet printers (a) and Spectra of black inks of different Canon inkjet printers (b)*

The spectra of two black inks Canon used in different types of Canon inkjet printers are on the Figure 7b. The shapes of the spectra differ mainly in the spectral range 550–1050 nm. So, the resolution of these spectra and hence inks is possible.

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