Richard A. Horton,[1] B.S. and Larry K. Nelson,[1] M.S.B.A.

An Evaluation of the Use of Laser-Induced Infrared Luminescence to Differentiate Writing Inks

REFERENCE: Horton, R. A. and Nelson, L. K., "**An Evaluation of the Use of Laser-Induced Infrared Luminescence to Differentiate Writing Inks,**" *Journal of Forensic Sciences*, JFSCA, Vol. 36, No. 3, May 1991, pp. 838–843.

ABSTRACT: An examination of 56 inks with an argon-ion laser revealed the laser will sometimes stimulate infrared luminescence in inks which did not produce infrared luminescence under the video spectral comparator (VSC-1). This infrared luminescence was always at a higher range (usually 830 to 900 nm) than that found under the VSC-1. This indicates that laser-induced infrared luminescence may be a useful tool in differentiating between inks which otherwise appear similar.

KEYWORDS: questioned documents, inks, luminescence, ink differentiation

The need for questioned-document examiners (QDEs) to be able to differentiate between two or more inks on a questioned document is quite obvious. Altered checks, money orders, legal contracts, wills, and other documents are commonplace. In many cases, the alterations are additions to original entries on the documents. These additions are often made with an ink of the same color as the original entry. The job of the QDE is to determine if the questioned document has been altered and, in some cases, to identify the ink that was used or the author of the additional entries.

Numerous studies on ink differentiation have been conducted using both visible and nonvisible light. These have included ultraviolet fluorescence (UVF), infrared luminescence (IRL), laser luminescence (LL), infrared reflectance (IRR), and laser-induced infrared luminescence (LIRL).

Laser-induced infrared luminescence using the argon-ion (AR) laser was reported by Dalrymple [*1*] who described case studies in which he observed LL when examining a number of postal-meter impressions, and, in one case, observed LIRL on an altered lottery ticket.

A study of various inks on standard check paper using neodymium/yttrium aluminum garnet (Nd:YAG) laser excitation was conducted by Zimmerman and Mooney [*2*]. These researchers also observed LIRL in a few instances, but did not discuss their observations in detail.

Several types of fluorescence, including LIRL, have been discussed in detail by Cantu

Presented at the 42nd Annual Meeting of the American Academy of Forensic Sciences, Cincinnati, OH, 19–24 Feb. 1990. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. Received for publication 4 June 1990; revised manuscript received 14 July 1990; accepted for publication 23 July 1990.

[1]Student questioned-document examiner and questioned-document examiner, respectively, U.S. Army Crime Laboratory (USACIL-CONUS), Ft. Gillem, GA.

and Prough [3]. Four inks were examined for LIRL, and the observed LIRL was noted to be concentrated between about 529 and 723 nm.

Varshneya et al. assembled a luminescence imaging document analyzer (LIDA) consisting of up to five different lasers to produce limited-range excitation wavelengths for projection on inks and paper [4]. Although they did not discuss specific results of the LIDA, they recognized that potentially useful information is lost when a wide band of wavelengths is used to excite luminescence because the luminescence produced is also over a wide band of wavelengths.

The purpose of this study was to gage the effectiveness of AR laser-induced infrared luminescence in differentiating samples of inks of the same color. Many of the inks examined were those frequently used in pens purchased by the U.S. Government. A number of other inks were also obtained to sample the inks on the open market.

This study attempted to answer two questions: would some inks which do not display normal IRL display LIRL, and, if so, would the LIRL merely be an amplification of a previously undetected IRL or a separate luminescence?

Experimental Method

Fifty-six writing instruments containing inks of four different colors were selected for this study (Table 1). The inks were contained in assorted types of writing instruments,

TABLE 1—*Results of wavelength tests on the 56 inks.*

Writing Instruments	IRR[a]	IRL	LL	LIRL
	Black Inks			
Skilcraft, U.S. Govt., ballpoint	N	N	N	N
Bic roller ball	Y	Y	N	Y
Parker roller ball, fine point[b]	Y	N	N	Y
Scripto, erasable, medium point	N	Y	Y	Y
Papermate, Eraser Mate 2	N	N	N	N
Papermate, medium point	Y	N	N	N
Pilot, razor point	Y	Y	N	Y
Faber-Castell, Uniball micro[b]	Y	N	N	Y
Cross, medium point	N	N	N	N
Nondescript ballpoint	N	N	N	N
Pentech Monami ballpoint (Korean)	Y	N	N	N
Faber-Castell Wonderwriter	Y	Y	N	Y
Skilcraft, U.S. Government, disposable	N	N	N	N
Sheaffer Tektor-tip marker	Y	Y	Y	Y
Amerigraph ballpoint	N	N	N	N
Cross, fine point	N	N	N	N
Tombow, rollpen	N	N	N	N
Kwik Klik, ballpoint	N	N	N	N
Bic, Ultrafine	Y	Y	N	Y
	Blue Inks			
Herlitz A3 ballpoint	Y	Y	N	Y
Skilcraft, U.S. Government ballpoint	Y	N	N	N
Papermate, medium point	Y	N	N	N
Papermate Eraser Mate 2[b]	Y	N	N	Y
Bic Biro, medium point	Y	N	N	N
Bic (Canon) ballpoint	Y	N	N	N
F-90 Fine Point USA ballpoint[b]	N	N	N	Y
Pilot BP-S fine point[b]	Y	N	N	Y
Herlitz, erasable, ballpoint[b]	Y	N	N	Y
Cross medium point ballpoint	Y	N	N	N

TABLE 1—*Continued.*

Writing Instruments	IRR[a]	IRL	LL	LIRL
Triangle ballpoint (German)	Y	Y	N	Y
Pentech Monami ballpoint (Korean)	Y	N	N	N
Nondescript pen	Y	Y	N	Y
Faber-Castell Uniball micro	Y	Y	Y	Y
Parker, washable fountain pen	Y	Y	N	Y
Pilot razor point	Y	Y	Y	Y
Ritepoint micro-tip No. 67	N	Y	N	Y
Garantie-Mine 424 medium point	Y	Y	N	Y
Scripto, erasable, medium point[b]	Y	N	N	Y
Parker, ballpoint, medium point	Y	N	N	N
Red Inks				
Pilot razor point roller ball	Y	Y	Y	Y
Faber-Castell Pinpoint	Y	Y	Y	Y
Berol Thinliner F-32	Y	Y	Y	Y
Nondescript ballpoint	Y	Y	N	Y
Pentech monami ballpoint (Korean)	Y	N	N	N
Berol disposable fountain pen	Y	Y	Y	Y
Papermate Eraser Mate 2	Y	Y	Y	Y
Papermate Plastic Point	Y	Y	N	Y
Audio Visual marker	Y	Y	Y	Y
Skilcraft, U.S. Government, disposable	Y	Y	N	Y
Faber-Castell, Uniball micro	Y	Y	N	Y
Spectra, fibertip	Y	Y	N	Y
Green Inks				
Pentech Monami ballpoint (Korean)	Y	N	N	N
Nondescript ballpoint	Y	N	N	N
Faber-Castell Uni-ball micro	Y	Y	N	Y
Faber-Castell Pinpoint	Y	Y	N	Y
Skilcraft felt tip	Y	Y	N	Y

[a]"Y" under IRR indicates ink became translucent at some wavelength upon IR stimulation.
[b]Inks which produced LIRL, but not IRL under the VSC-1.

including ballpoint pens, felt-tip markers, rollerball pens, and even a few fountain pens. Some of the pens were of foreign manufacture. Six of the inks were erasable.

The wavelength range of the Spectra-Physics AR laser used in this research is 487.9 to 514.5 nm. It was applied at an 8-W output level during the examinations. The AR laser generates an intense blue-green light, similar in appearance to that used by the VSC-1 to produce IRL.

The inks were examined in our laboratory for IRL using a video spectral comparator (VSC-1) by Foster and Freeman, Ltd. The excitation light of the VSC-1 is produced by a 500-W tungsten halogen bulb. Two LP1 filters and a heat-reflecting filter restrict the light to wavelengths below about 625 nm (concentrated between about 425 and 525 nm), which appears blue-green in color. Therefore, the laser does not emit most of the wavelengths which are excitation sources for the VSC-1.

Each ink was written onto two types of paper: white U.S. General Services Agency (GSA) prescribed Standard Forms (SF) 1164 (claims forms) and white Nashua Data-Print Xerographic bond, a paper frequently used in government copying machines. Three full lines of writing were placed on each sheet.

The inks were initially examined for UVF and then scanned on the VSC-1 for IRR and IRL. Each ink was then examined for LL with the AR laser and scanned on an

IRDE 1200 document examiner's Kit. The IRDE 1200 is a portable device consisting of a Pulnix IR-sensitive camera (Model PU-34), 25-mm lens, ×2 converter, 9-in. (23-cm) RCA black and white monitor, and an Olympus 12-V, 30-W portable light source with blue-green filter slides. The IRDE 1200 was used for comparison purposes since the same equipment (minus the light source) was used to conduct the examinations for LIRL.

The examinations for LIRL involved moving the IRDE 1200 to the AR laser and substituting the laser for the Olympus light source. Each specimen was then examined on both the front and back for LIRL and LIRL transference from one sheet to another. Any resulting LIRL was observed on the RCA monitor.

Results

None of the inks examined produced detectable UVF. Twenty-eight inks produced IRL under the VSC-1. The same 28 inks also produced LIRL. In addition, 7 of the remaining 28 inks which did not produce IRL under the VSC-1 produced LIRL. The results are summarized as follows:

- 6 black inks (32%) produced IRL under the VSC-1; an additional 2 (11%) produced LIRL;
- 8 blue inks (40%) produced IRL under the VSC-1; an additional 5 (25%) produced LIRL;
- 11 red inks (92%) and 3 green inks (60%) produced IRL under the VSC-1; no additional inks produced LIRL;
- all of the 28 inks (50%) which produced IRL under the VSC-1 also produced LIRL (Fig. 1); and
- 7 inks (13%) which did not produce IRL under the VSC-1 did produce LIRL (Fig. 2) (this represented 25% of the remaining inks which did not display IRL).

No LIRL was noted on the back of a sheet, or in any location indicative of transference. The individual results are listed in Table 1.

Discussion

The LIRL was different from the IRL produced using the VSC-1 in three respects:

1. All inks which displayed IRL in the 680 to 750-nm range displayed LIRL in the same range, but the luminescence was much brighter.
2. None of the inks which displayed IRL in the 680 to 750-nm range displayed IRL at longer wavelengths. Under LIRL, however, all of these inks displayed a weak luminescence out to approximately 900 nm.
3. Seven inks which did not display any IRL displayed weak LIRL in the 800 to 900-nm range.

It is not clear whether these differences are due to the greater intensity of the laser as an excitation source or the narrow band of wavelengths of light produced by the laser. It is not known whether the laser is simply increasing the brightness and visibility of luminescence which was produced in limited or undetectable quantities by the VSC-1, or whether it is exciting luminescence not produced by the VSC-1 at all.

Four inks (three red, one blue) produced extremely weak IRL in the range of 680 to 750 nm under the IRDE 1200 with the Olympus 30-W light source, but did not produce detectable IRL under the VSC-1. In addition, the inks displayed stronger LIRL within the same range, extending out to the 800 to 900-nm range. The absence of detectable IRL under the VSC-1 could be due to a lesser intensity of the excitation source or to differences in the sensitivity of the camera units to infrared light. It should be noted that

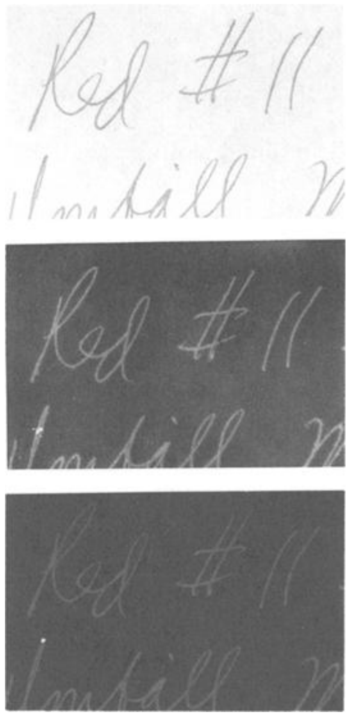

FIG. 1—*Red ink No. 11* (top) *and as it appeared, producing IRL under the VSC-1 at 715 nm* (middle) *and LIRL under the AR laser at 830 nm* (bottom.) *(Note: all photographs were exposed with a Polaroid MP-3 4 by 5-in. camera, 105-mm lens, and Kodak Technical Pan film. Photographs by D. Dietz.)*

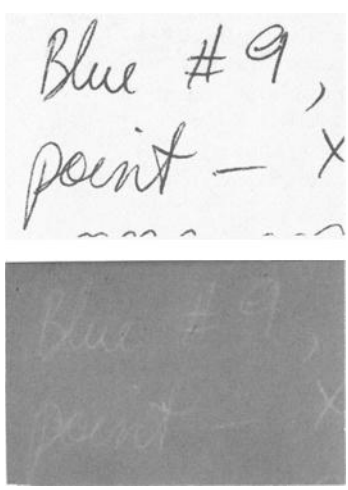

FIG. 2—*Blue ink No. 9* (top) *and as it appeared producing LIRL under the AR laser at 830 nm* (bottom). *This ink did not produce IRL under the VSC-1 or IRDE 1200.*

Foster and Freeman, Ltd. has an equipment upgrade available that may improve the ability of the VSC-1 to excite and detect IRL. The purpose of this paper was to evaluate the use of LIRL to differentiate between inks which did not produce IRL under the VSC-1. Nevertheless, the four inks which produced IRL under the IRDE 1200 were not included with the seven subject inks in this report. These four inks are mentioned only because they were easily differentiated because of significant production of LIRL in the 800 to 900-nm range.

Conclusions

These experiments demonstrate that laser-induced infrared luminescence can be a useful tool in the examination of writing inks, subject to the cautions pointed out by Sensi and Cantu regarding the possible effects of outside contaminants on masking compounds within inks [*5*]. The use of LIRL in addition to IRR, IRL, and LL significantly improves the ability of the examiner to differentiate between two inks of the same color.

Acknowledgments

The authors would like to thank the following people for their assistance:

Bill Jungbluth, latent print examiner, for technical advice and assistance with the AR laser on this project; Dave Flohr, forensic chemist, for several discussions and explanations which resulted in both the initiation and understanding of this study; and Dave Deitz, photographer, for photographic support.

References

[*1*] Dalrymple, B. E., "Visable and Infrared Luminescence in Documents: Excitation by Laser," *Journal of Forensic Sciences*, Vol. 28, No. 3, July 1983, pp. 692–696.

[*2*] Zimmerman, J. and Mooney, D., "Laser Examination as an Additional Nondestructive Method of Ink Differentiation," *Journal of Forensic Sciences*, Vol. 33, No. 2, March 1988, pp. 310–318.

[*3*] Cantu, A. A. and Prough, R. S., "Some Spectral Observations of Infrared Luminescence," *Journal of Forensic Sciences*, Vol. 33, May 1988, pp. 638–647.

[*4*] Varshneya, D., Jeffers, L. A., and Noblett, M. G., "Laser Scanning of Inks," *Proceedings of the International Symposium on Questioned Documents, 30 July–1 Aug. 1985*, U.S. Government Printing Office, Washington, DC.

[*5*] Sensi, C. A. and Cantu, A. A., "Infrared Luminescence: Is It a Valid Method to Differentiate Among Inks?" *Journal of Forensic Sciences*, Vol. 27, No. 1, Jan. 1982, pp. 196–199.

Address requests for reprints or additional information to
Richard A. Horton, Student Questioned-Document Examiner
U.S. Army Crime Laboratory (USACIL-CONUS)
Ft. Gillem, GA 30050-5000