

TECHNICAL NOTE

Ian P. Hayward,¹ Ph.D.; Tracy E. Kirkbride,¹ M.Sc.; David N. Batchelder,¹ Ph.D.; and Richard J. Lacey,² Ph.D.

Use of a Fiber Optic Probe for the Detection and Identification of Explosive Materials by Raman Spectroscopy

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ABSTRACT: A fiber optic probe has been developed that allows Raman spectra to be acquired remotely from a spectrometer. This system has been used to acquire spectra from explosive materials. In this study we demonstrate that it is sufficiently sensitive to rapidly detect traces of PETN in fingerprints of Semtex-H explosive. Further development of similar systems will enable the detection and non-destructive identification of contraband materials in the field.

KEYWORDS: criminalistics, spectroscopic techniques, Raman, fiber optic, explosive, spectroscopy, non-destructive testing

Forensic scientists can use a variety of laboratory techniques to identify prohibited materials such as explosives and narcotics. Previous work [1–3] has shown that Raman spectroscopy has several advantages over other techniques; it is rapid, requires little sample preparation, and is non-destructive.

There are many situations where the scientist would like to use Raman spectroscopy to detect and identify trace samples of explosives and narcotics away from the laboratory, for example, at the scene of a crime. We are investigating the use of remote fiber optic probes as the first and most important stage of developing portable Raman systems. This paper details a preliminary study of the remote Raman spectroscopy of fingerprints contaminated with Semtex plastic explosive.

Experiment and Results

Semtex-H has two active ingredients, cyclotrimethylene-trinitramine (RDX) and pentaerythritol-tetranitrate (PETN). A fingerprint of this material was created by pressing a finger onto the Semtex and then onto aluminum foil. This sample is thus the first in a "depletion series" [4]; subsequent fingerprints will contain fewer and fewer explosive crystals (although their size will remain

roughly constant). The quantity of explosive in the fingerprint was not determined, but is believed to be in the microgram range.

The experimental arrangement is shown in Fig. 1. A 4 m long, 50 μm core diameter, silica optical fiber supplies the fiber-optic probe head (FOPH) with 633 nm light from a 25 mW helium-neon laser (Spectra-Physics). The light is collimated by a singlet lens, and then passed through a line filter. The filter transmits at the frequency of the laser, but stops other frequency light, such as that produced by the laser's discharge tube, and by Raman scattering within the fiber. The laser light is reflected by a holographic (notch) filter and then focused onto the sample by a microscope objective lens. The same objective collects the backscattered light and directs it towards the holographic filter. The filter transmits the Raman shifted light, while preventing the elastically scattered Rayleigh light from reaching the fiber that connects the FOPH to the spectrometer. This reduces the intensity of the reflected and Rayleigh scattered light by 10^5 , and prevents the light from generating spurious signals by exciting Raman scattering within the fiber. The polychromatic Raman scattered light is coupled into the 50 μm diameter spectrometer fiber by an achromatic lens. The end of the 4 m long fiber from the FOPH was mounted on the microscope stage of the spectrometer, a Renishaw Raman Imaging

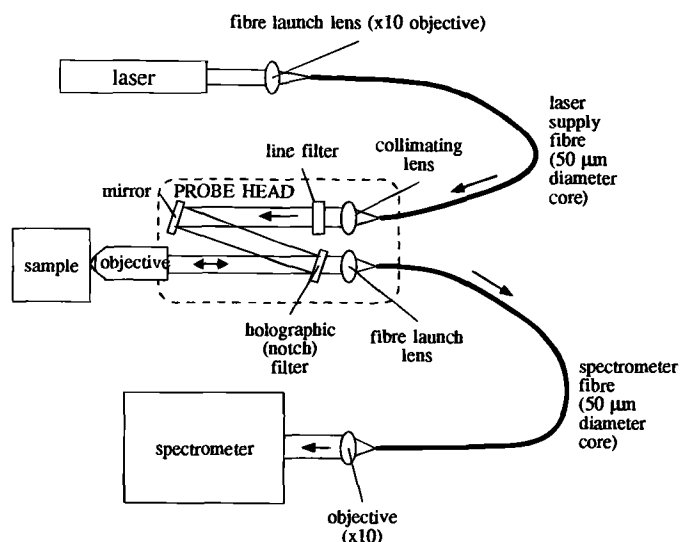


FIG. 1—Schematic diagram of the fiber optic system.

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¹Department of Physics, University of Leeds, Leeds, England.

²Police Scientific Development Branch, St. Albans, England.

Microscope [5], in the normal sample position. The Microscope's $\times 10$ objective was used to image the fiber into the spectrometer, as it is well matched to the numerical aperture of the fiber.

The choice of objective to use on the FOPH is a compromise between collection efficiency and depth of field. In this case a $\times 50$ objective was used, with a numerical aperture of 0.8 and a depth of field of $40\ \mu\text{m}$ (FWHM). This objective was chosen for its high collection efficiency; its relatively low depth of field was not a problem because the specimens studied were all prepared on flat aluminum foil. The spot size on the sample is dependent on the magnification; in this case the spot diameter was approximately $10\ \mu\text{m}$.

The sample was mounted in front of the FOPH's objective on an xyz stage. The distance of the sample from the objective was adjusted to maximize the intensity of the attenuated Rayleigh scattered light entering the spectrometer. The sample was then moved laterally while the spectrometer monitored the intensity of Raman scattered light in the range $400\text{--}1300\ \text{cm}^{-1}$ (using $0.1\ \text{s}$ exposures of the multichannel CCD detector). The movement was stopped when a strong peak at $880\ \text{cm}^{-1}$ from RDX or PETN was detected. A spectrum was then taken over the range $200\text{--}3200\ \text{cm}^{-1}$. This spectrum (Fig. 2) consists of the spectrum of PETN superimposed on a broad background, with an additional peak in the C-H region at $2900\ \text{cm}^{-1}$. The non-PETN features are produced by either trace amounts of luminescent finger grease, or resin from the Semtex, or a combination of the two.

Discussion and Conclusions

The preliminary result presented here shows that it is feasible to locate and identify traces of explosive in a fingerprint using a fiber optic probe that is $4\ \text{m}$ distant from the spectrometer. It is possible to use longer fibers successfully because the attenuation in the fiber is not severe at the excitation wavelength used ($633\ \text{nm}$).

Several issues need to be addressed before practical systems can be developed. In the experiment described here the sample was flat, allowing easy positioning in front of the FOPH. Suitable positioning aids will be required for use in field conditions. The system will also have to be as rugged as possible to fully exploit the advantages of convenience and flexibility of fiber-based fiber optic probes.

References

- [1] Batchelder, D. N., Cheng, C., Hayward, I. P., Lacey, R. J., Pitt, G. D., and Sheldon, T. G., "Raman Microscopy and Direct 2-D Imaging of Explosives and Drugs," *Proceedings of the Contraband and Cargo Inspection Technology International Symposium*, sponsored by Office

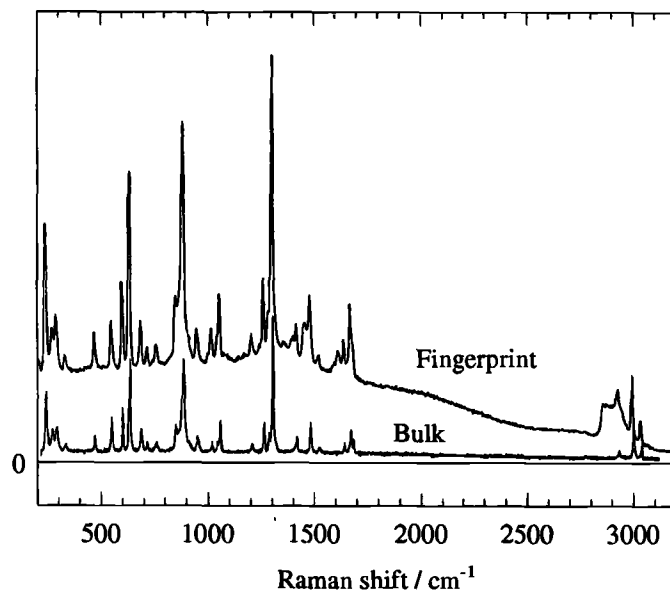


FIG. 2—Raman spectrum of bulk PETN taken with a standard (non fiber optic) Renishaw Spectrometer (25 mW laser), and a spectrum of part of the fingerprint on aluminum taken using the FOPH (25 mW laser). Relative scalings are arbitrary. The total acquisition time for each spectrum was 40 s.

- of National Drug Control Policy and National Institute of Justice, Washington, D.C., Oct. 1992, pp. 73–75.
- [2] Cheng, C., Kirkbride, T. E., Batchelder, D. N., Lacey, R. J., and Sheldon, T. G., "In-Situ Detection and Identification of Trace Explosives by Raman Spectroscopy," *Journal of Forensic Sciences*, in press.
- [3] Chaffin, N. C., Daniel, N. W., Jr., Lewis, I. R., and Griffiths, P. R., "The Study of Explosives Using Raman Spectroscopy and Feed-Forward Neural Networks," *Proceedings of the Fourteenth International Conference on Raman Spectroscopy*, Hong Kong, Aug. 1994, pp. 894–895.
- [4] Neudorfl, P., McCooeye, M. A., and Elias, L., "Testing Protocol for Surface-Sampling Detectors," *Proceedings of the Fourth International Symposium on the Analysis and Detection of Explosives*, 337, Jerusalem, Sept. 1992, pp. 373–384.
- [5] Williams, K. P. J., Pitt, G. D., Smith, B. J. E., Whitley, A., Batchelder, D. N., and Hayward, I. P., "The Use of a Rapid Scanning Stigmatic Raman Imaging Spectrograph in the Industrial Environment," *Journal of Raman Spectroscopy*, Vol. 25, 1994, pp. 131–138.

Address requests for reprints or additional information to
Ian P. Hayward, Ph.D.
Dept. of Physics
University of Leeds
Leeds LS2 9 JT
England