

Non-invasive detection of cocaine in rum using displaced Raman spectroscopy

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Introduction

Currently, one of the major routes for smuggled cocaine into the UK involves dissolution of the drug in common alcoholic beverages such as rum. Relatively large quantities of the drug (of the order of 100's of grams) can be concealed inside a single bottle and then separated upon arrival at its destination by simple evaporation of the liquid content. A single bottle can be carried by a smuggler across an entry port into the country; larger quantities can be concealed within a consignment of genuine drink bottles. The detection of such items is extremely difficult, particularly in the latter case, as currently there are no simple, effective and rapid means of inspecting such samples without opening each individual bottle. There is clearly a strong need in this area for a fast, portable non-invasive detector of concealed drugs. In this work, we demonstrate that a variant of Raman spectroscopy, Displaced Raman spectroscopy developed through access to the LSF's Ultrafast Spectroscopy Laboratory, fulfils these requirements.

This research builds on our earlier work on the detection of powder and liquid explosives in plastic and other types of packaging, both transparent and diffusely scattering

(translucent). In these experiments we used a variant of Spatially Offset Raman Spectroscopy (SORS)^[1,2,3], we call here Displaced Raman Spectroscopy^[4] to distinguish it from standard SORS. A major advantage of the concept is that any interfering Raman and fluorescence contributions originating from the bottle itself are effectively suppressed as demonstrated experimentally in our earlier work on liquid explosives, which also included highly fluorescing glass bottles^[4]. Fluorescence emission can be a particularly severe problem for conventional backscattering Raman spectroscopy of coloured bottles (typically brown or green) where, in some cases, it can pose an insurmountable obstacle by swamping the weaker Raman signal^[5].

An additional advantage is that the Displaced Raman geometry automatically acts, i.e. with no need for reconfiguration, as a standard SORS method when presented with diffusely scattering samples (e.g. an opaque white plastic bottle) rather than transparent containers^[4]. This feature substantially broadens its applicability. In the Displaced Raman concept, the basic delivery of the laser radiation into the bottle through its wall is accomplished by sending a narrow, weakly focused laser beam into the sample at an angle, typically $\sim 45^\circ$, such that the beam

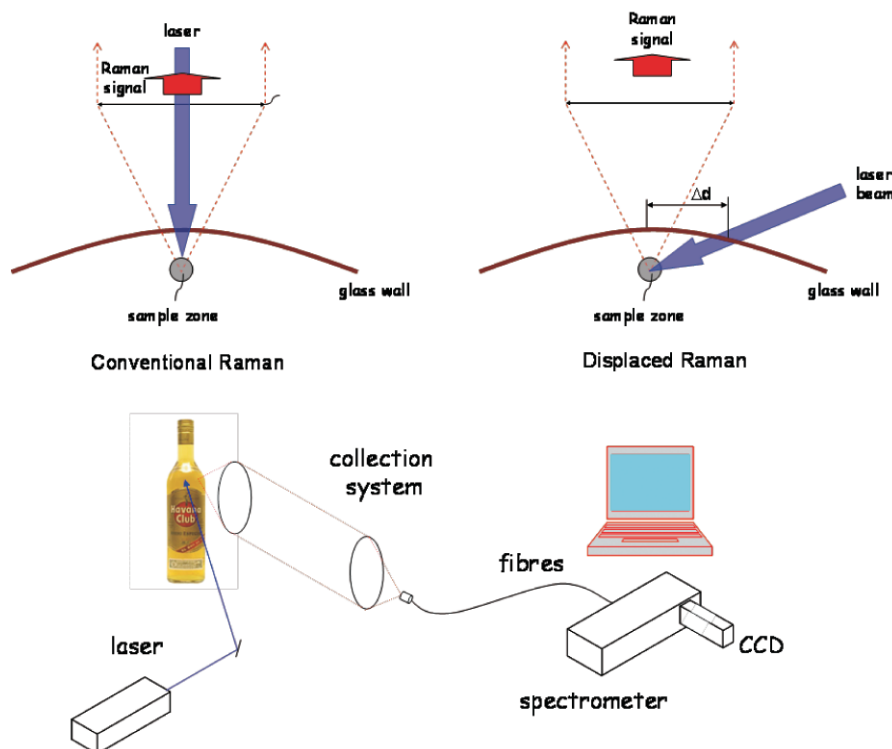


Figure 1. a) Schematic diagrams of the experimental geometries for conventional backscattering Raman and Displaced Raman spectroscopy. b) Overall experimental layout used in the non-invasive measurements.

intersects the Raman collection zone located within the contents of the bottle (see figure 1). A more detailed account of this work is given in reference^[6].

Experimental section

Apparatus

The experimental apparatus used in the detection of dissolved cocaine was configured as follows. The probe beam was generated using a temperature stabilised diode laser for Raman spectroscopy operating at 830 nm (Process Instruments Inc, PI-ECL-830-300-FS). The laser power at the sample was 250 mW with a laser spot diameter of ~1 mm. The laser beam was brought onto the sample at a 45° angle with a displacement from the collection axis (Δd) of 10 mm (see figure 1a). The collection zone was placed ~10 mm below the surface of the probed bottle. The acquisition time for each spectrum was 1 s.

Samples

Samples were prepared by dissolving ~300 g of adulterated cocaine (75 % pure) in 'Havana Club Añejo Especial Golden Rum' beverage (0.7 l, 40 % alcohol by volume, ethanol concentration ~7 moles per litre) corresponding to a pure cocaine concentration of ~1 mole per litre. The sample was probed in the original brown glass bottle. An identical bottle with no cocaine was used in control measurements.

Results and discussion

The results of the non-invasive probing of the rum bottles with and without cocaine are shown in figure 2. The Raman spectrum without the cocaine is dominated by ethanol; the other principal component, water, is a very weak Raman scatterer. The presence of cocaine results in the appearance of new, intense, Raman bands in agreement with those reported earlier for cocaine in powder form^[7]. In particular the intense doublet at around 1000 cm^{-1} , spectrally distinct from the major bands of ethanol, can serve as an easy marker for the presence of this substance. The detection limit of the method is estimated (from the measured signal to noise ratio) to be ~12 g of adulterated cocaine (75% pure cocaine) per 0.7 l.

The linear dependence of Raman signal on sample concentration offers the possibility of using measured Raman intensities for the determination of the relative concentration of cocaine in the bottle by simply comparing the intensities of the ethanol and cocaine bands.

The use of displaced Raman spectroscopy also provides the potential for monitoring other illicit substances, either in powder or liquid form, concealed in plastic, diffusely scattering bottles with the same experimental arrangement as reported earlier for liquid explosives^[4]. The simplicity of the concept makes it amenable for adoption in conventional portable Raman instruments permitting deployment of the technique in the field. In combination with automated data processing and band assignment, this would also eliminate the need for a specialist to interpret the Raman data.

Conclusions

We have demonstrated a variant of Raman spectroscopy that is a viable tool for the rapid, non-invasive, detection of

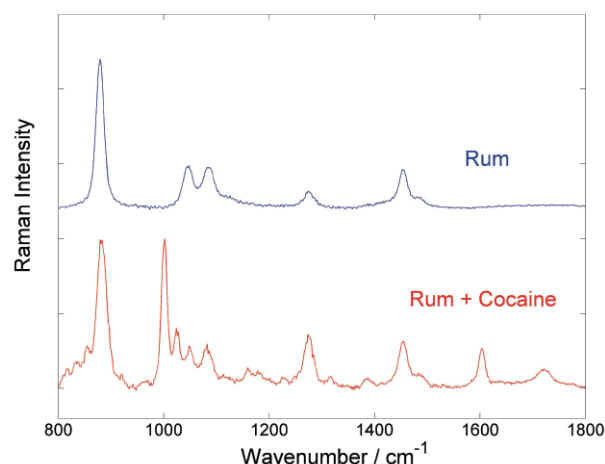


Figure 2. The results of the non-invasive probing of bottles containing rum with (top trace) and without dissolved cocaine (bottom trace). The Raman spectrum of pure rum is dominated by ethanol. The presence of cocaine results in the appearance of new Raman bands. The spectra were measured using a probe wavelength of 830 nm, laser power of 250 mW and 1 s acquisition time.

cocaine concealed within alcoholic beverages. A ~300 g solution of cocaine (purity 75 %) was detected non-invasively in a 0.7 l glass bottle of rum with good sensitivity within 1 s acquisition time. The sensitivity limit for pure cocaine in this application is estimated to be around 9 g per 0.7 l (0.07 moles per litre) with 1 s acquisition time.

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