Application Note

Non-invasive Detection of Concealed Liquid and Powder Explosives

The application of Spatially Offset Raman Spectroscopy (SORS) enables rapid and accurate identification of concealed liquids and powders, including those used as explosives or their precursors. The application of SORS to non-invasive chemicals detection is described here.

The non-invasive detection of explosives and their precursors through containers or packaging presents a considerable challenge. The difficulty in detecting these substances is compounded by the wide variety of packaging in which they can be readily concealed. Raman spectroscopy holds great potential in this area due to its high chemical specificity and compatibility with mixtures and with water. However, a major problem with conventional Raman stems from the fluorescence and Raman interference of the packaging, which overwhelms the weaker contents signals. Here we demonstrate that SORS[i] substantially improves the performance of Raman spectroscopy in this application.[ii,iii]

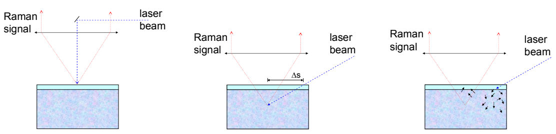

Figure 1: Schematic illustration of (left) conventional Raman geometry SORS concept with (mid) transparent and (right) diffusely scattering containers.

The SORS approach relies on the collection of Raman spectra from spatial regions *offset* from the point of illumination on the sample surface (see Figure 1). This suppresses fluorescence and Raman signals generated by the container walls and permits interrogation of both transparent and diffusely scattering containers with a single instrument.

Method

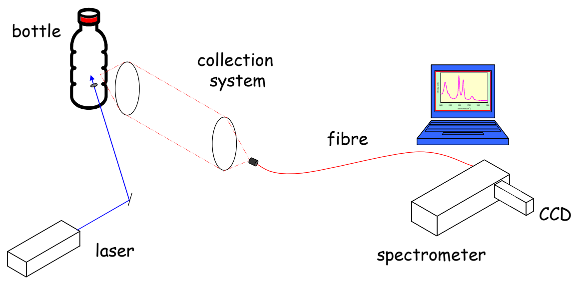

Figure 2: SORS measurements performed on bottles.

The experiments were performed using an 830nm laser with 250mW average power. The acquisition times were 1s for each spatial offset. The signal was collected in two subsequent measurements, with zero and 10mm offsets. The zero spatial offset measurement was used to remove the residual Raman spectrum of the surface (container wall) from the 10mm offset Raman spectrum by a scaled subtraction. The scaled subtraction was performed 'blind', i.e., in an automated way with no human intervention. The pure Raman spectrum of the bottle content can then be compared with a library data set containing known explosive constituents using standard procedures.

Experiments were performed on common containers typically used by passengers in carry-on luggage with the contents substituted for 30% hydrogen peroxide solution (H_2O_2 (aq)). Hydrogen peroxide is a critical constituent of a number of liquid explosive mixtures and is readily available for bleaching hair. H_2O_2 could be smuggled on board an aircraft either pre-mixed with other chemicals or as a separate component. For the explosive to be effective a relatively concentrated solution of hydrogen peroxide is required, such as 30%. In a separate experiment sugar was used in the same containers to demonstrate the ability of the technique to detect powder explosives.

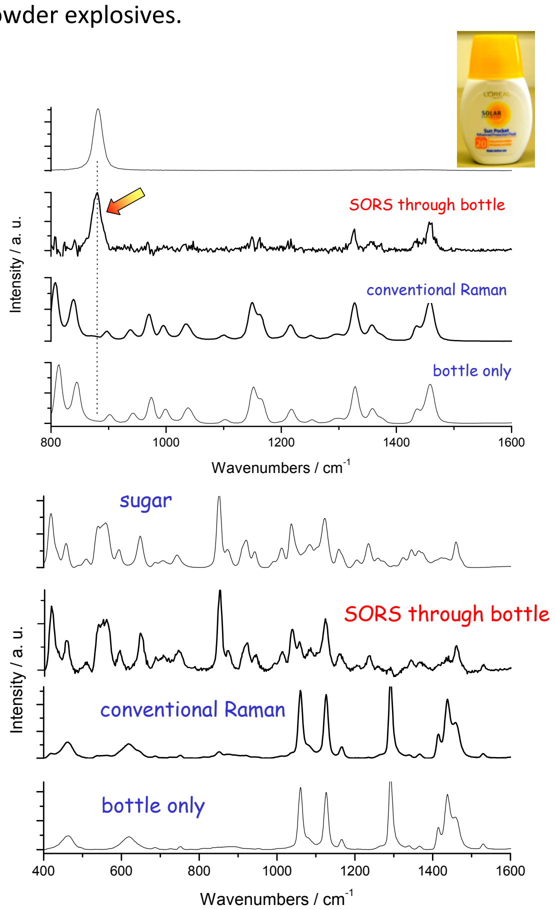

Figure 3: Conventional and SORS Raman spectra of a L'Oreal sun lotion bottle filled with 30% aqueous H_2O_2 (upper) and sugar (lower). The container wall was 1.1 mm thick.

Results

The results of probing a white plastic bottle are shown in figure 3. The container is highly diffusely scattering and presents an insurmountable challenge for conventional Raman spectroscopy where the marker Raman band of H_2O_2 at 876cm^{-1} is completely swamped by signals originating from the container wall. In contrast, SORS eliminates the surface Raman signal and permits straightforward identification of the compound through its characteristic marker band. We estimate the Raman signal could be detected if the H_2O_2 solution was diluted by 10x, i.e., a limit of detection of around a few percent.

Detection of powder explosives concealed in the same plastic bottle is also illustrated in Figure 3. In this case, sugar was used to mimic an explosive substance. The conventional Raman method is again ineffective but SORS removes the overwhelming surface signal and permits interrogation of the bottle contents. The powder identity could also be established when the analysed samples were inside green fluorescing glass bottles, wrapped in a layer of 0·3mm thick cotton cloth or held within an envelope.

Conclusions

This work demonstrates the effectiveness of the SORS approach in detecting liquid and powder explosives concealed in a wide range of plastic containers including white plastic bottles. Many common containers were also successfully assessed to test breadth of applicability: plastic and glass, transparent and opaque, coloured versus white, etc. Full details can be found elsewhere.[ii,iii]

i P. Matousek, I.P. Clark, E.R.C. Draper, M.D. Morris, A.E. Goodship, N. Everall, M. Towrie, W.F. Finney, A.W. Parker, *Appl. Spectrosc.* **59**, 393 (2005).
ii C. Eliasson, N.A. Macleod, P. Matousek, *Anal. Chem.* **79,** 8185 (2007).
iii C. Eliasson, N.A. Macleod, P. Matousek, *Vibrational Spectroscopy* **48**, 8 (2008).