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Looking through the glass: Probing concealed samples in closed containers using shaped laser light

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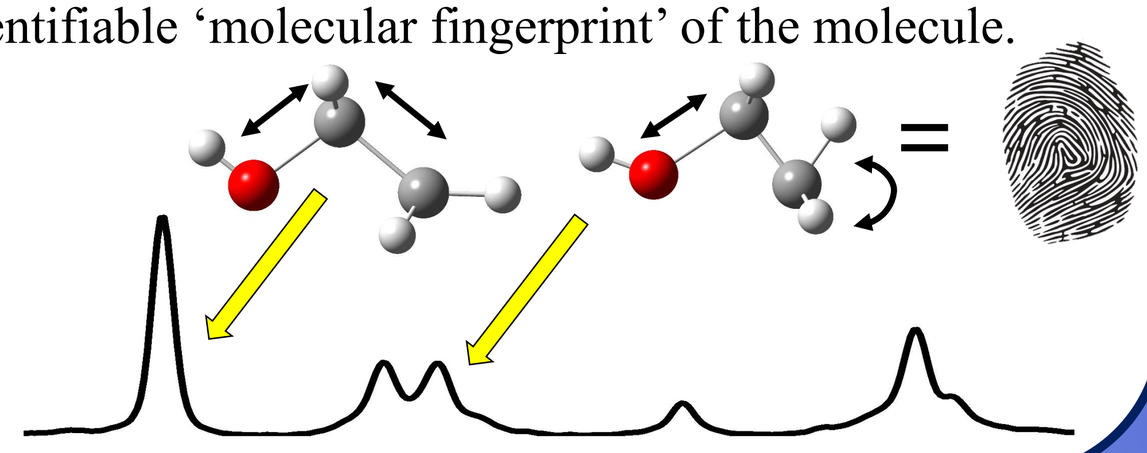
Applications

Opening a container in order to identify its contents is often undesirable and can depreciate its value. The ability to rapidly, non-destructively characterise the contents of a sealed container without the need to open it, would therefore be of great benefit in areas such as:

- Product quality control: food, drink and pharmaceuticals
- Aviation security
- Forensics and anti-counterfeiting

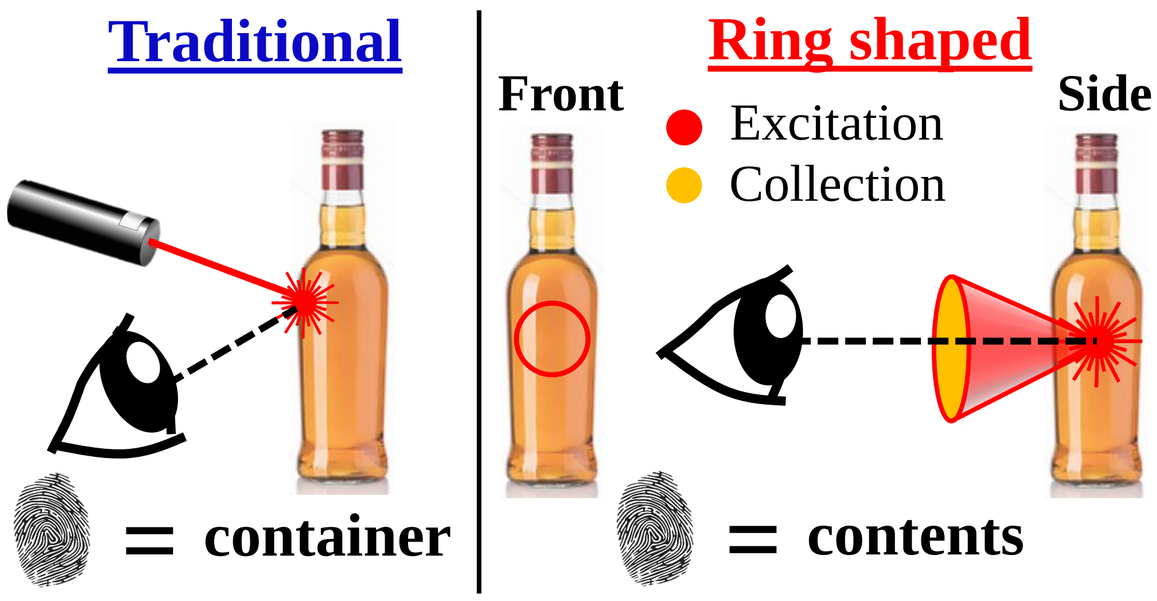
Raman Spectroscopy

All molecules vibrate in different ways. Raman spectroscopy is a rapid, non-destructive technique that can measure these vibrations using laser excitation. A unique vibrational signature (Raman spectrum) of the molecule is generated, which function as a unique, identifiable 'molecular fingerprint' of the molecule.



Methodology: Focus Matching

Traditional Raman measurements are performed using a laser spot focused on the sample's surface. However, this is not well suited to concealed samples as the majority of the signal collected contains the molecular fingerprint of the surface material, not of the contents.

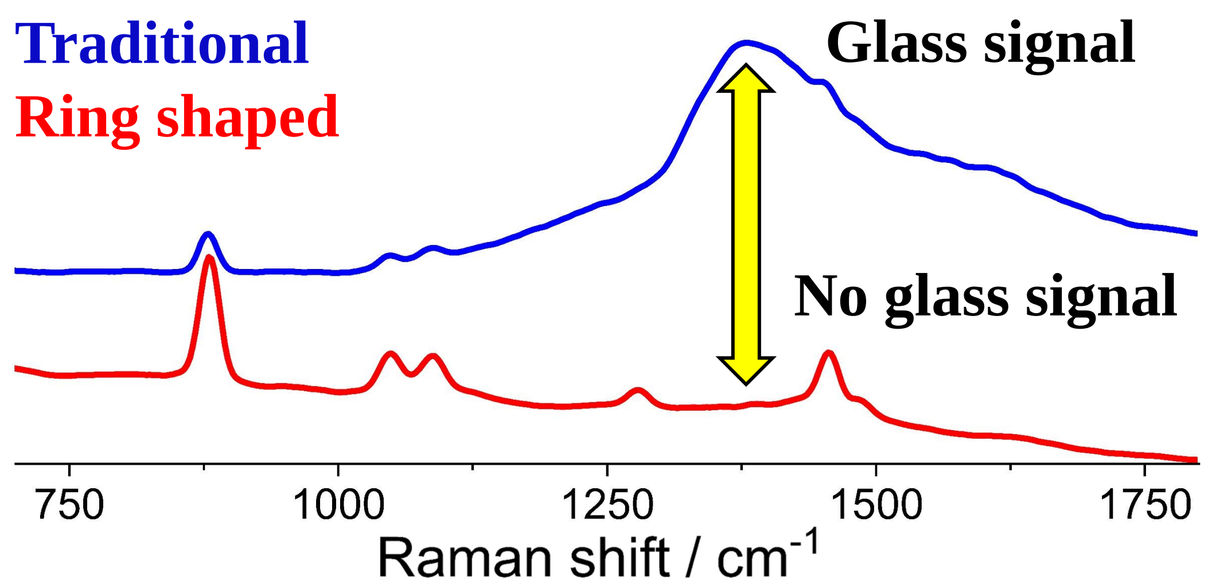


In order to address this problem, our optical setup is designed such that exciting laser is ring shaped on the sample surface, but focuses to a point *inside* the sample. It is from this point where we collect our Raman signal.

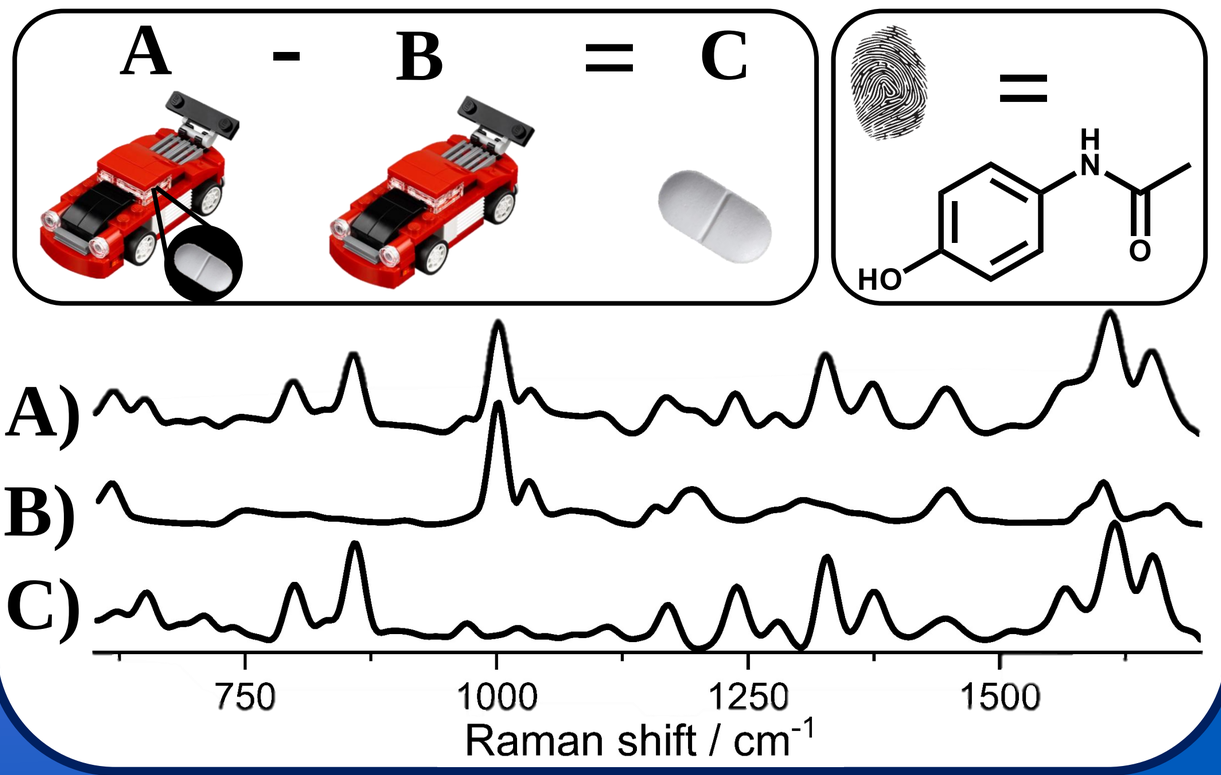
This annular 'focus-matched' geometry allows signal from the surface to be largely excluded, collecting signal from the hole in the ring, whilst simultaneously boosting signal from the internal contents.

Results: Sealed Sample Analysis

Strong fluorescence from glass bottles usually hinders traditional Raman analysis of their contents. However, using our geometry, the glass signal can be entirely excluded and the bottle's contents, like that of whisky shown below, can be measured directly through the bottle.



In addition, a paracetamol tablet concealed inside a Lego car was also successfully detected. Due to the thick, opaque nature of the container, spectral subtraction of the container spectrum, as shown below, was required to obtain a pure fingerprint of the hidden contents.



Summary

The use of shaped laser light combined with overlapping collection and excitation points beyond the container wall, allows Raman spectra of concealed samples to be obtained. This Raman fingerprint can then be used to rapidly determine the nature of the concealed sample, all without opening the container.

Shillito, G. E; McMillian, L.; Bruce, G. D.; Dholakia, K., *accepted in Opt Express* **2022**, doi:10.1364/OE.451496;
Fleming, H.; Chen, M.; Bruce, G. D.; Dholakia, K. *Anal. Methods* **2020,** *12*, 4572-4578.

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