Quantitative Stand-off Spectroscopy and Trace Detection

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INTRODUCTION

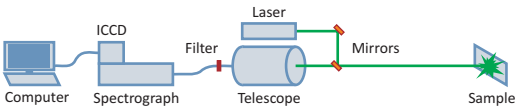
We present our latest achievements in quantitative stand-off Raman spectroscopy and a practical application for stand-off Raman trace detection.

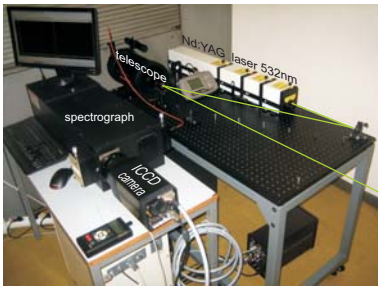
Quantitative single analyte detection of stand-off Raman at a distance of 9 meters is shown by the example of sodium chloride pellets containing varying amounts of ammonium nitrate (0-100%).

Traces of ammonium nitrate on aluminium plates were analysed to evaluate the limits of this technique.

Furthermore, we were able to detect traces of ammonium nitrate left by a fingerprint from a distance of 12 metres.

STAND-OFF RAMAN INSTRUMENTATION

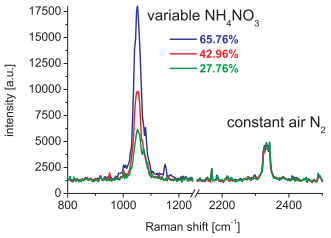




The stand-off Raman system employed uses a frequency doubled Q-switched Nd:YAG laser operating at 532 nm (pulse length 4.4 ns at 10 Hz) aligned coaxially with a 6" Schmidt-Cassegrain telescope for the collection of Raman scattered light. The telescope is coupled via a fibre optic cable to an Acton standard series SP-2750 spectrograph and a PI-MAX 1024RB intensified CCD (iCCD) camera equipped with a 500 ps gating option for detection.

During all measurements the laser and iCCD camera were synchronised so that the measurement window coincided with the maximum Raman signal, minimising the signal contributions from fluorescence and ambient light.

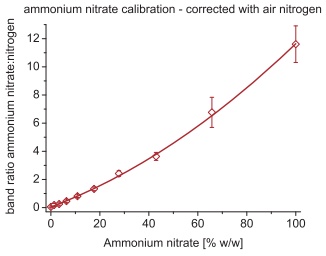
UNIVARIATE QUANTIFICATION



For univariate Raman stand-off quantification at a distance of 9 meters NaCl and NH_4NO_3 were mixed and compacted into pellets.

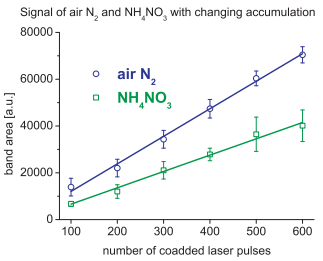
Selected stand-off Raman spectra of NH_4NO_3/NaCl pellets of different ammonium nitrate concentration are shown on the left.

The NH_4NO_3 band changes with concentration whereas the nitrogen signal from air is constant.



The band ratio of NH_4NO_3 (950 - 1150 cm^{-1}) and N_2 (2280 and 2380 cm^{-1}) increases with NH_4NO_3 concentration.

Spectra were normalised to the intensity of the atmospheric N_2 band to correct the measured NH_4NO_3 signals.



To show that this technique compensates for instrumental fluctuations, the signal collection time was varied while measuring a 10.85% NH_4NO_3 pellet.

With longer collection time the signal of NH_4NO_3 (green) increases. As the atmospheric nitrogen band (blue) increases as well, the ratio of NH_4NO_3 and N_2 is constant.

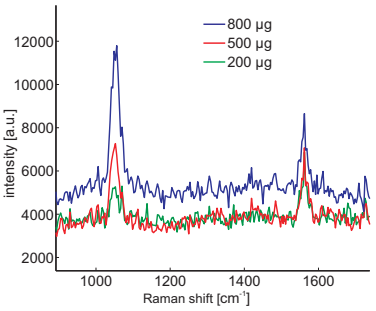
An average of six measurements are shown; the error bars represent the 95% confidence band.

TRACE QUANTIFICATION

To evaluate the limits of this quantification technique different amounts of ammonium nitrate were deposited on aluminium plates.

The stand-off distance between sample and instrument was 18 meters. A laser power of 65.9 mJ per pulse was used. 600 single spectra were accumulated, taking 60 seconds.

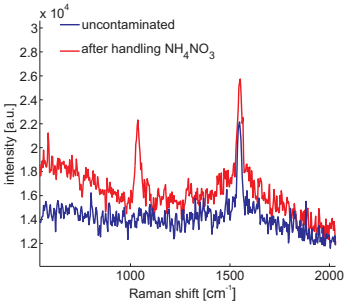
To quantify NH_4NO_3, the 902 - 1063cm^{-1} band was used. For this method, a LOD of 117 µg was calculated.



TRACE DETECTION - FINGERPRINTS

To give an example of the power of stand-off Raman spectroscopy, we took spectra of fingerprints on aluminium plates. One produced by a person with uncontaminated hands, one by a person who had handled powdered NH_4NO_3, then touched about fourty other, clean surfaces and finally the aluminum plate.

Stand-off Raman spectra of the sample were collected from a distance of 12m with a laser power of 100 mJ and by accumulating 600 single spectra with a gate of 5 ns each.



It was possible to detect traces of NH_4NO_3 left by the fingerprint.

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