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Sensitive detection of aerosols and gases using Raman scattering

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2nd Internation Conference & Exhibition on Lasers, Optics and Photonics

September 08-10, 2014

This work was sponsored by the Edgewood Chemical Biological Center portion of this work was sponsored by the Defense Threat Reduction Agency under Air Force Contract FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the United States Government.

Outline

- Introduction to Raman scattering
- Schematic of the Raman setup
- Detection of aerosols
- Detection of gases
- Summary
- Acknowledgments

Introduction to Raman Scattering

- Raman scattering (inelastic light scattering due to molecular vibrations and/or rotations) was first observed by Prof. C. V. Raman on February 28, 1928 using the light from a Hg arc lamp. The results of this experiment were published on March 31, 1928.
- Lasers are now used for Raman scattering experiments.
- Raman spectrum of a material is its molecular *fingerprint.*
- Raman cross sections are very very small ($1x10^{-30}$ - $1x10^{-25}$ cm^2).

Sir C. V. Raman (1888 – 1970)
1930 Nobel Prize for Physics

Raman Signal

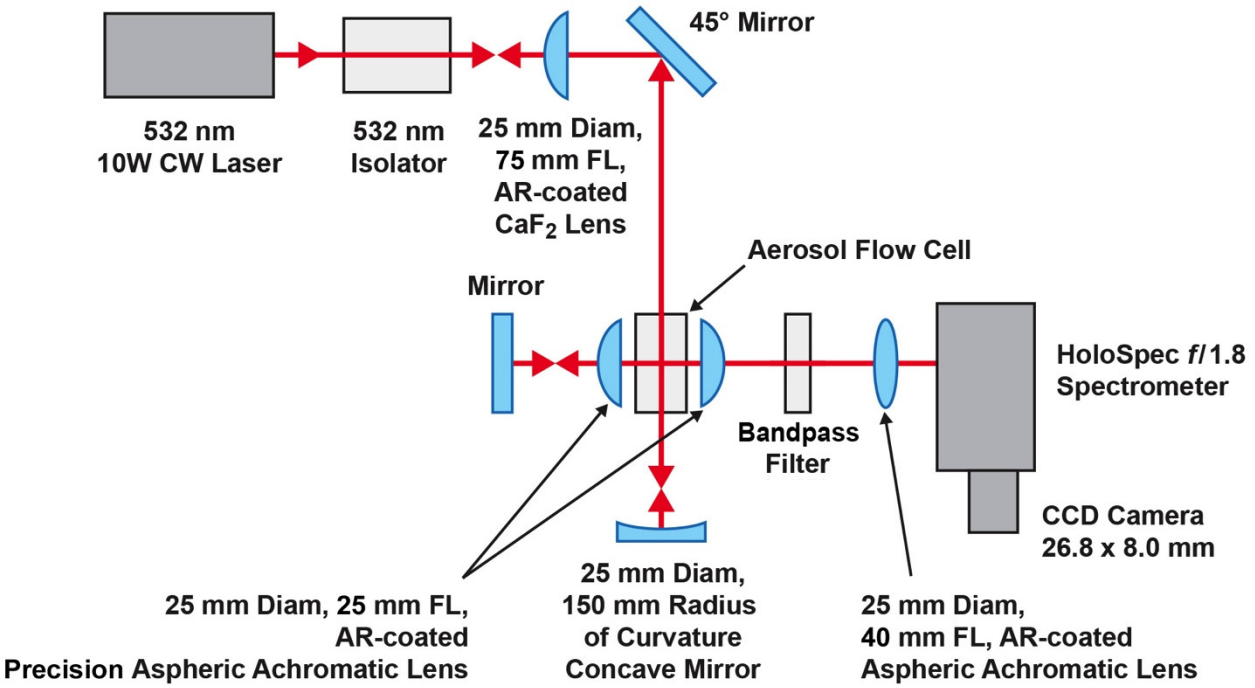
Raman signal S_R (CCD counts) is given by

$$S_R = \eta_c \eta_q \sigma_R N_m L (P_L \tau / h\nu_L)$$

where
- η_c = Collection efficiency
- η_q = CCD quantum efficiency
- σ_R = Raman cross section (cm^2)
- N_m = Molecular concentration (cm^{-3})
- L = Laser path length (cm)
- P_L = Laser power (W)
- τ = Integration time (s)
- $h\nu_L$ = Laser photon energy (J)

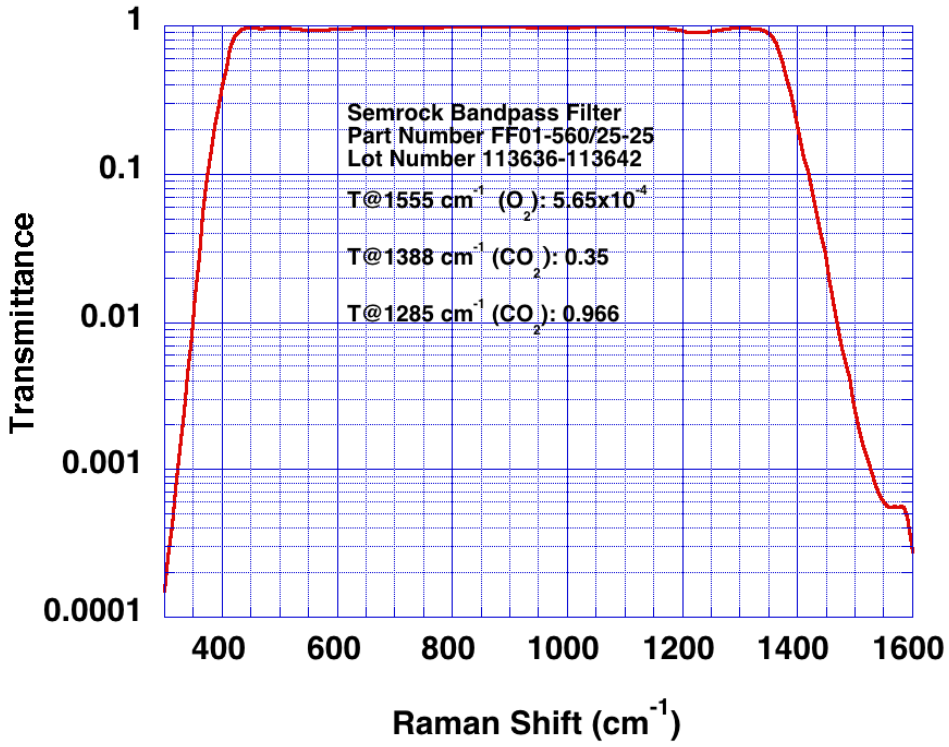
Relative Raman signals for different materials are determined by the value of the product of σ_R *and* N_m.

Schematic of the Raman Setup



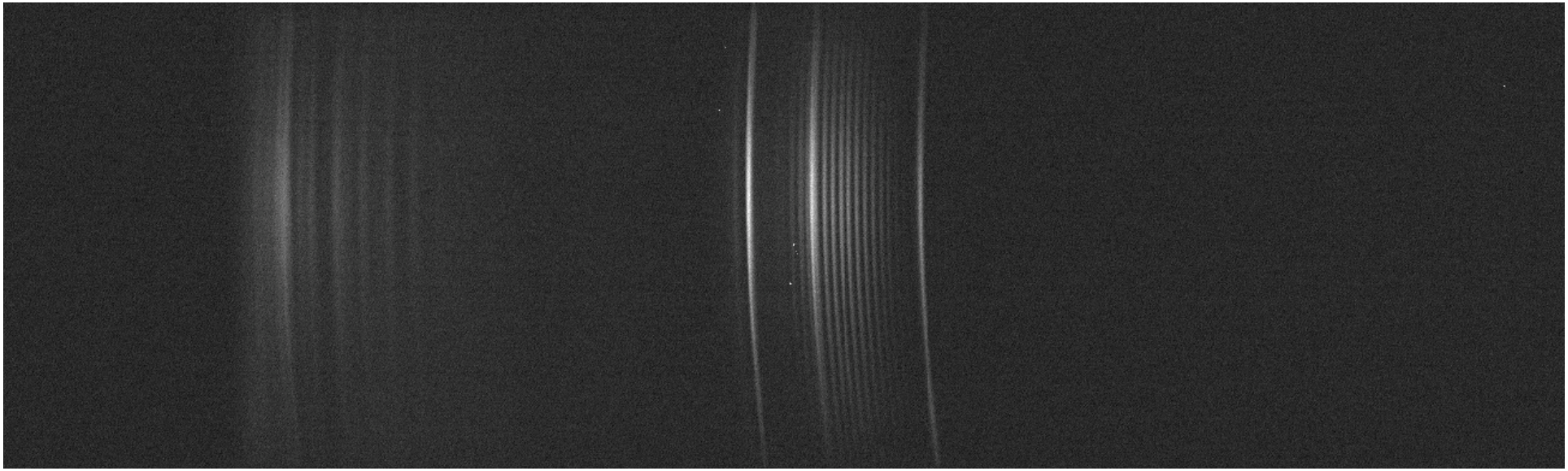
The spectral resolution is 10 cm^{-1} using the standard grating and 4 cm^{-1} using the high-dispersion grating.

Transmittance of the Bandpass Filter



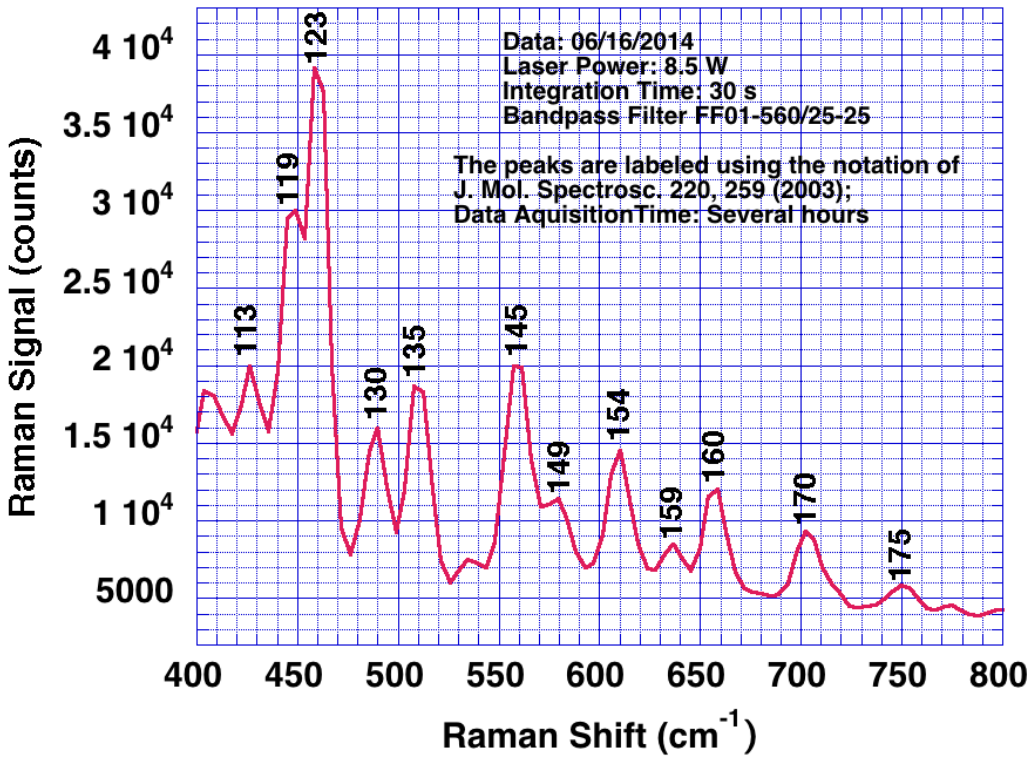
~ 98% transmittance over the 430-1350 cm^{-1} spectral range

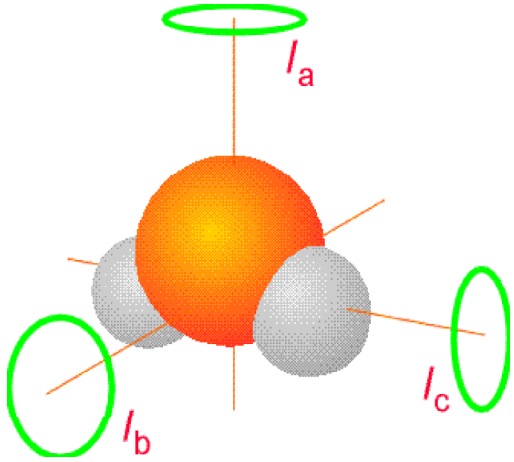
The CCD Image Obtained with Standard Grating and 30 s Integration Time



H_2O CO_2 O_2

H_2O Rotational Spectrum Using Standard Grating





Rotational constants:

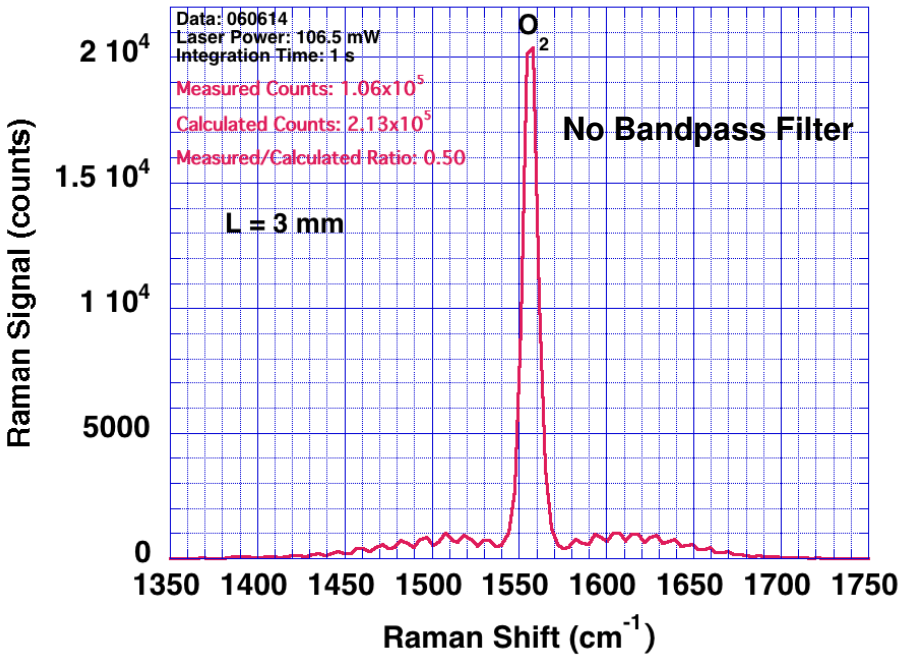
$A = h/8\pi^2 c I_a = 27.9\ \text{cm}^{-1}$

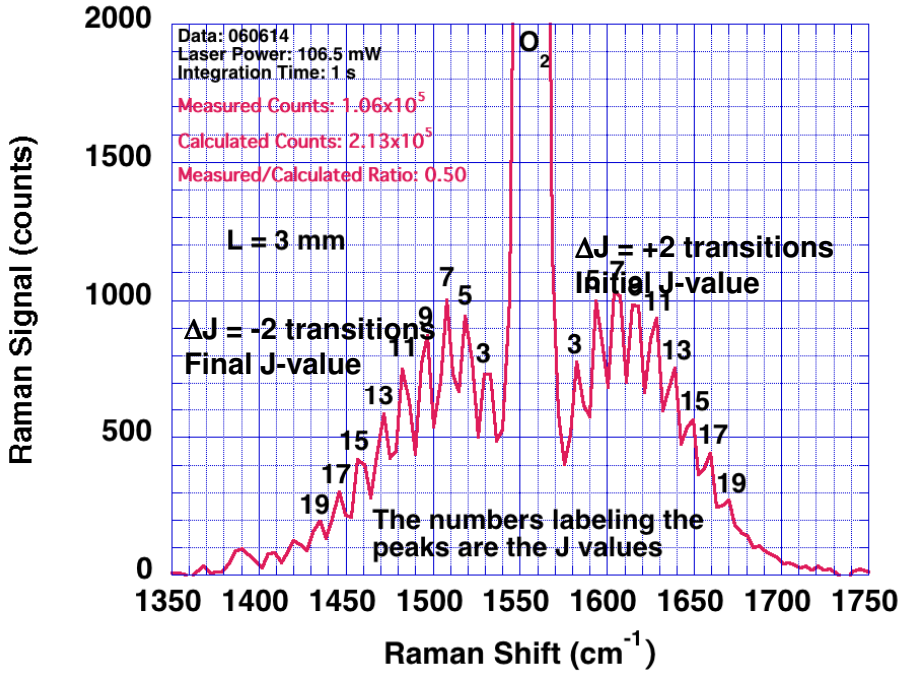
$B = h/8\pi^2 c I_b = 14.5\ \text{cm}^{-1}$

$C = h/8\pi^2 c I_c = 9.3\ \text{cm}^{-1}$

The peaks are labeled using the notation of Avila et al., J. Mol. Spectrosc. 220, 259 (2003).

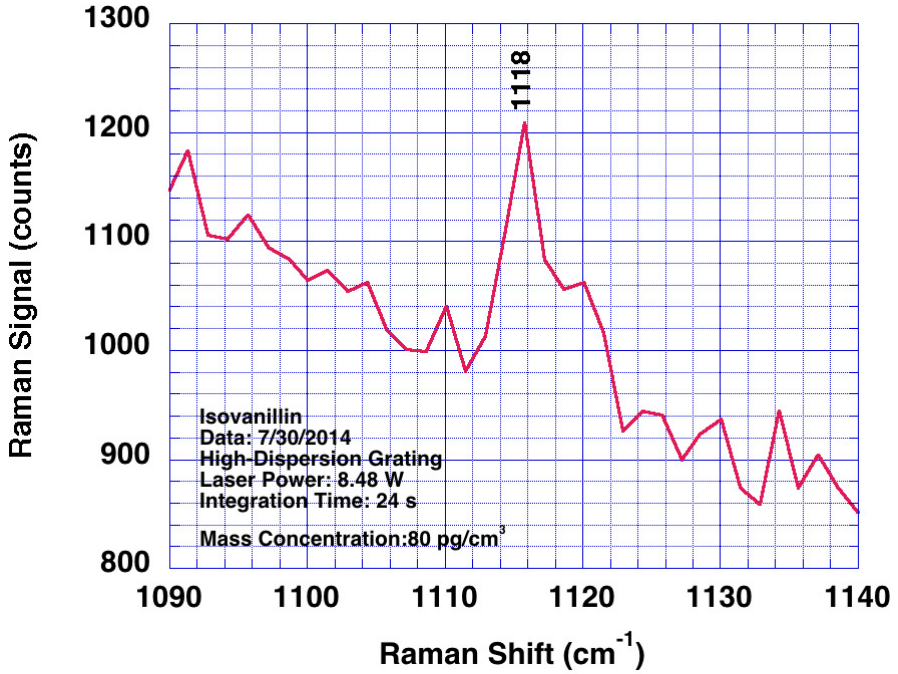
Performance of Our Raman Setup Using the Standard Grating Without Bandpass Filter





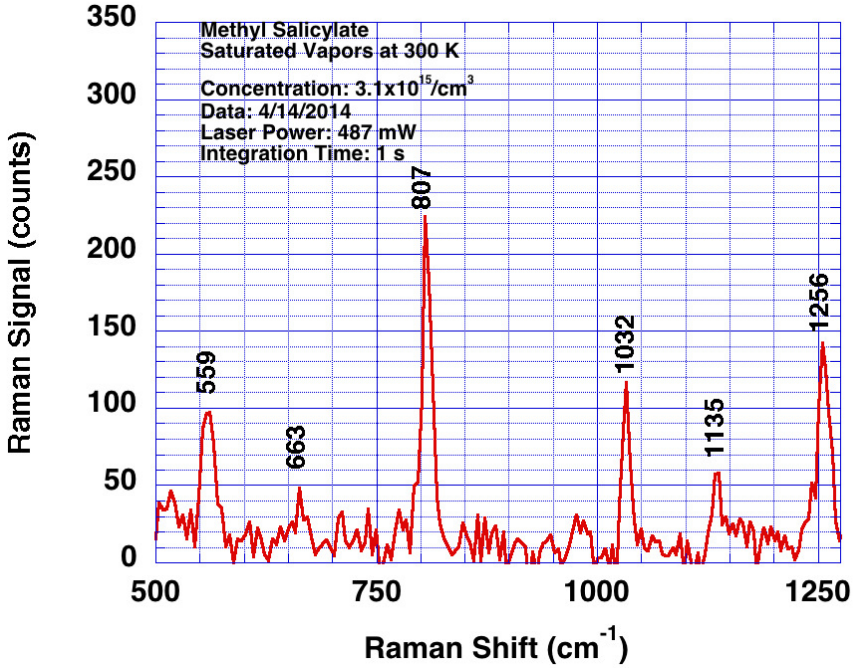
(i) The measured value of the Raman signal is 2x smaller than that of the calculated value, partly due to vignetting of the rays from off-axis points on the laser beam. (ii) The selection rule for rotational transitions is $\Delta J = \pm 2$, where J is the rotational quantum number and even J transitions are completely missing. The most populated level at 300 K is $J = (kT/2hcB)^{1/2} - 1/2 = 8$; B is the rotational constant equal to 1.45 cm^{-1} for O_2.

Detection of Isovanillin Aerosol Using High-Dispersion Grating



Limit of detection < 80 pg/cm^3

Detection of Methyl Salicylate Vapors Using Standard Grating



- **Limit of detection deduced to be < 2 ng/cm^3 using 10 W laser power and 30 s integration time.**

- **σ_R for the 807 cm^{-1} mode determined to be 2.80±0.17x10^{-29} cm^2**

Summary

- Limit of detection < 80 pg/cm^3 in 24 s for isovanillin aerosol using the high-dispersion grating. σ_R is equal to 3.3x10^{-28} cm^2 for the 1116 cm^{-1} mode.

- Limit of detection deduced to be < 2 ng/cm^3 for methyl salicylate vapors for 10 W laser power and 30 s integration time using the standard grating. The value of σ_R has been determined to be 2.80±0.17x10^{-29} cm^2 for the 807 cm^{-1} mode.

Acknowledgments

- David Sickenberger (ECBC)
- Steven Christensen (ECBC)
- Max Howe (MIT Lincoln Laboratory)

Thanks for listening to me.

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