One Spectrometer, Two Spectra: Complementary Hemispherical Reflectance and Thermal Emission Spectroscopy Using a Single FTIR Instrument

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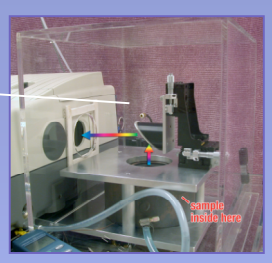
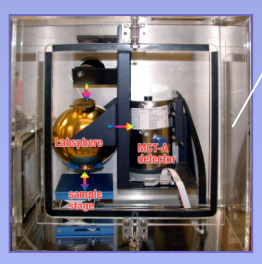
Advantages of a Dual System

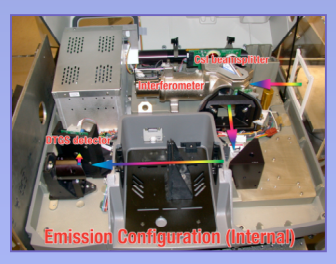
- **Emission measurements**
  - Directly comparable to remote sensing measurements
  - Can cover longer wavelengths using DTGS detector than reflectance
    - to ~50 μm vs. 15 - 25 μm
  - Directly comparable to hemispherical reflectance measurements via Kirchhoff's Law (R = 1 - ε) [*Salisbury et al.*, 1994]
  - But few laboratories make these measurements
- **Reflectance measurements**
  - More traditional
  - Covers shorter wavelengths than emission using MCT-A detector
    - to ~2.5 μm vs. 5 μm
  - Hemispherical reflectance comparable to emission via Kirchhoff's Law
- **Both data sets can be collected nearly simultaneously** (within tens of minutes)
  - Get two data sets for comparison to multiple spectral libraries
  - Avoids long-distance transport
    - doesn't disturb delicate samples
    - emission and reflectance spectra can be acquired of ~identical surfaces in the case of particulate materials
  - Utilize reflectance spectra to determine true minimum of Christiansen feature and use this to accurately determine maximum emissivity value
  - Short wavelength features in reflectance data may aid in spectral identification of low-abundance phases

The Spectrometer





- Thermo Electron Nexus 470 FTIR
- Cesium iodide (CsI) beamsplitter
- Internal, TE-cooled deuterated triglycine sulfate (DTGS) detector
- Ports on left and right sides for external attachments
  - right - emission
  - left - reflectance



Hemispherical Reflectance

- IR source inside spectrometer illuminates the sample via a path exiting the viewing port on the left side of the spectrometer and entering the top of the Au-coated Labsphere integrating sphere, which sits over sample [similar to *Salisbury et al.*, 1991]
  - Spot size is ~1.5 cm diameter
- Reflected signal measured is at an external, liquid N_2-cooled mercury cadmium telluride (MCT-A) detector from ~2.5 – 15.4 μm (~4000 to 650 cm^{-1}) (*see pictures above*)
- Sample spectra ratioed to spectrum of a diffusely reflecting gold plate [*Johnson et al.*, 1998]
  - residual atmospheric components can be suppressed using spectrometer software (Figure R3)

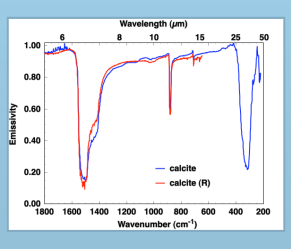


Figure R1. Comparison of solid calcite spectra acquired in reflectance and emission at UH. Slight differences in spectral shape result from viewing different spot sizes.

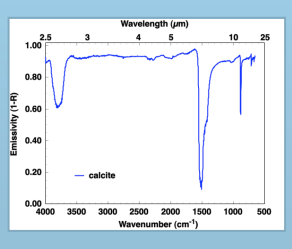


Figure R2. Hemispherical reflectance (shown as emission) spectrum of calcite showing full spectral range of reflectance configuration.

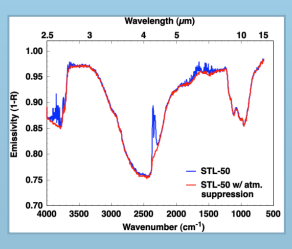


Figure R3. Red spectrum demonstrates improvement obtained by using atmospheric suppression software. STL-50 is a 710-1000 μm particulate sample of gabbronorite.

Emission

- Configuration identical to that at Arizona State University [*Ruff et al.*, 1997]; hot sample is positioned in a double-walled, water-cooled Cu-chamber
  - Chamber is maintained at constant T; allows calculation of downwelling radiance
  - Spot size observable is selectable from focal point to ~4-5 cm
- Sample energy enters spectrometer via right-hand port and is measured at the internal, TE-cooled DTGS detector from ~5 – 50 μm (~2000 to 200 cm^{-1}) (*see pictures above*)
- Sample calibration follows two-temperature method of [*Ruff et al.*, 1997]
  - Spectra shown here are qualitative; high-precision & accuracy blackbody calibration targets currently are being fabricated, with delivery anticipated in Q2 of 2005

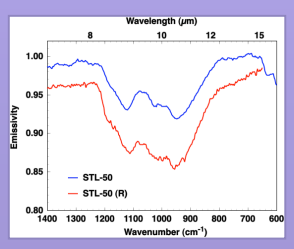


Figure E1. Comparison of emission and reflectance spectra acquired at UH. Spectra are shown as calibrated, with no offset or filtering. Both spectra acquired with 270 scans and at 2 cm^{-1} sampling (4 cm^{-1} resolution).

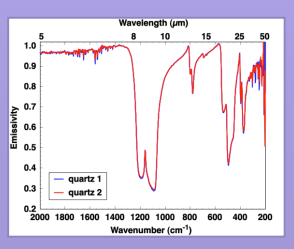


Figure E2. Repeatability spectra of solid quartz. Resolution is 4 cm^{-1}, 270 scans, no filtering, measurements acquired ~5 min. apart in an unpurged environment. High frequency features between 1800 - 1400 & 350 - 200 cm^{-1} are atmospheric water vapor.

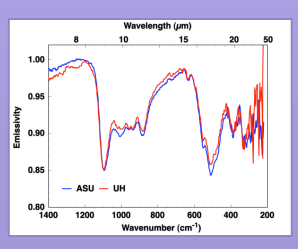


Figure E3. Comparison of Zagami emission spectra acquired at ASU and UH. Small deviations in band shapes are the result of viewing slightly different surfaces on rock chip. UH spectrum acquired in unpurged environment.

References: S. W. Ruff et al., *JGR, 102*, 14,899-14,913 [1997]; J. R. Johnson et al., *Rem. Sens. Env., 64*, 34 - 46 [1988]; J. W. Salisbury et al., *Infrared (2.1 - 25 μm) Spectra of Minerals*, JHU Press [1991]; J. W. Salisbury et al., *JGR, 99,* 11,897 - 11,911 [1994]

Acknowledgements: S. Ruff (ASU) and W. Koeppen (UH) contributed significantly to the initial setup of the emission experiment; P. Christensen & G. Mehall (ASU) provided blueprints and insight. VEH supported by NASA PG&G NAG5-12145