National Aeronautics and Space Administration

NASA

Standoff Ultra-Compact μ-Raman Sensor for Human Research

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Engineering Directorate

Concept-to-Flight

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Team Members of Standoff Ultra-compact μ-Raman Sensor

Participants:

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Our technology helps NASA Human Exploration Mission to monitor astronauts' health by detecting biomarkers: biofluids (e.g., urine, serum, etc), tissues, and cells in space

Standoff Ultra-Compact μ-Raman Sensor…

Our Story

We developed a Standoff Ultra-Compact micro-Raman Sensor at NASA LaRC under NASA Planetary Instrument Concepts Advancement for Solar System Observations (PICASSO) program and also LaRC investment funds (IRAD).

This sensor was used for inspection and identification of water, ice, minerals, organic, and biomarkers (Amino acids, e.g., L-Glutamine, L-Phenylalanine, etc.) that are associated with life.

The big pivot is from planetary to medical science applications for human exploration missions from Moon to Mars for astronauts' health monitoring in space under NASA Human Exploration and Operation Mission Directorate (HEOMD).

Standoff Ultra-Compact μ-Raman Sensor…

Planetary Science Investigation to Human Research

Funding Resource: Planetary Science Division (PICASSO) & LaRC (IRAD)

SUCR Sensor (LaRC)

Human Research (Astronauts' Health Monitoring in Space)

Inspect & Identify Biomarkers: Urine, Blood, Cells, Tissues, or Bodily Fluids

Objectives

Inspect and identify the normal and abnormal cells, tissues, and biofluids (e.g., urine, serum, etc.) using a 532 nm pulsed laser within target distances of several centimeters (6 to 20 cm) and a line-shaped laser spot-size 10 μm width by 5 mm height that would be suitable for astronauts' health monitoring in space.

Goals

The goals of this research study are:

- Solve some of the limitations of traditional micro-Raman systems (e.g., requires dark condition, sample collection, and slow)
  - ➢ build an instrument with pulsed-time gated Raman technology, operates in daylight, doesn't require sample collection, and faster detection

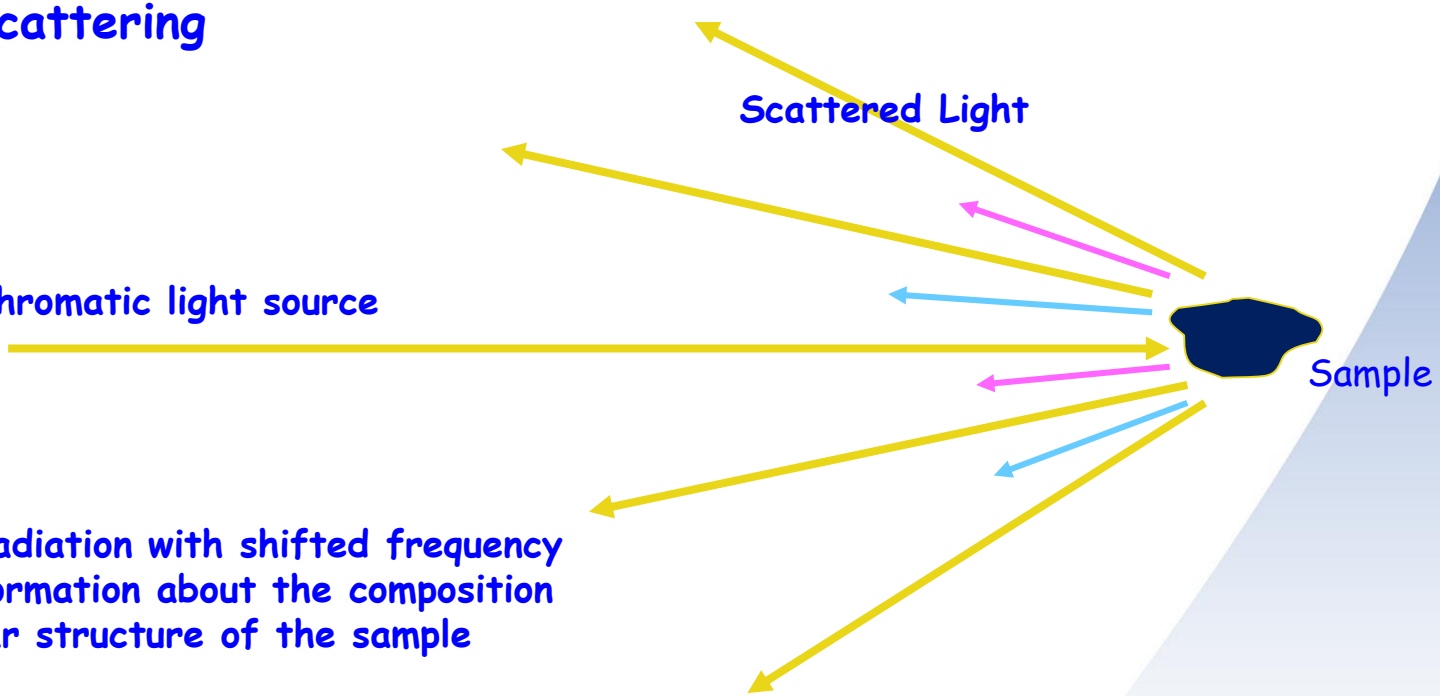
- Reduce the size and weight of the instrument
  - ➢ eliminate a high power laser and a large collection optics/telescope with a short working distance of several centimeters.

Standoff Ultra-Compact μ-Raman Sensor…

Raman Spectroscopy

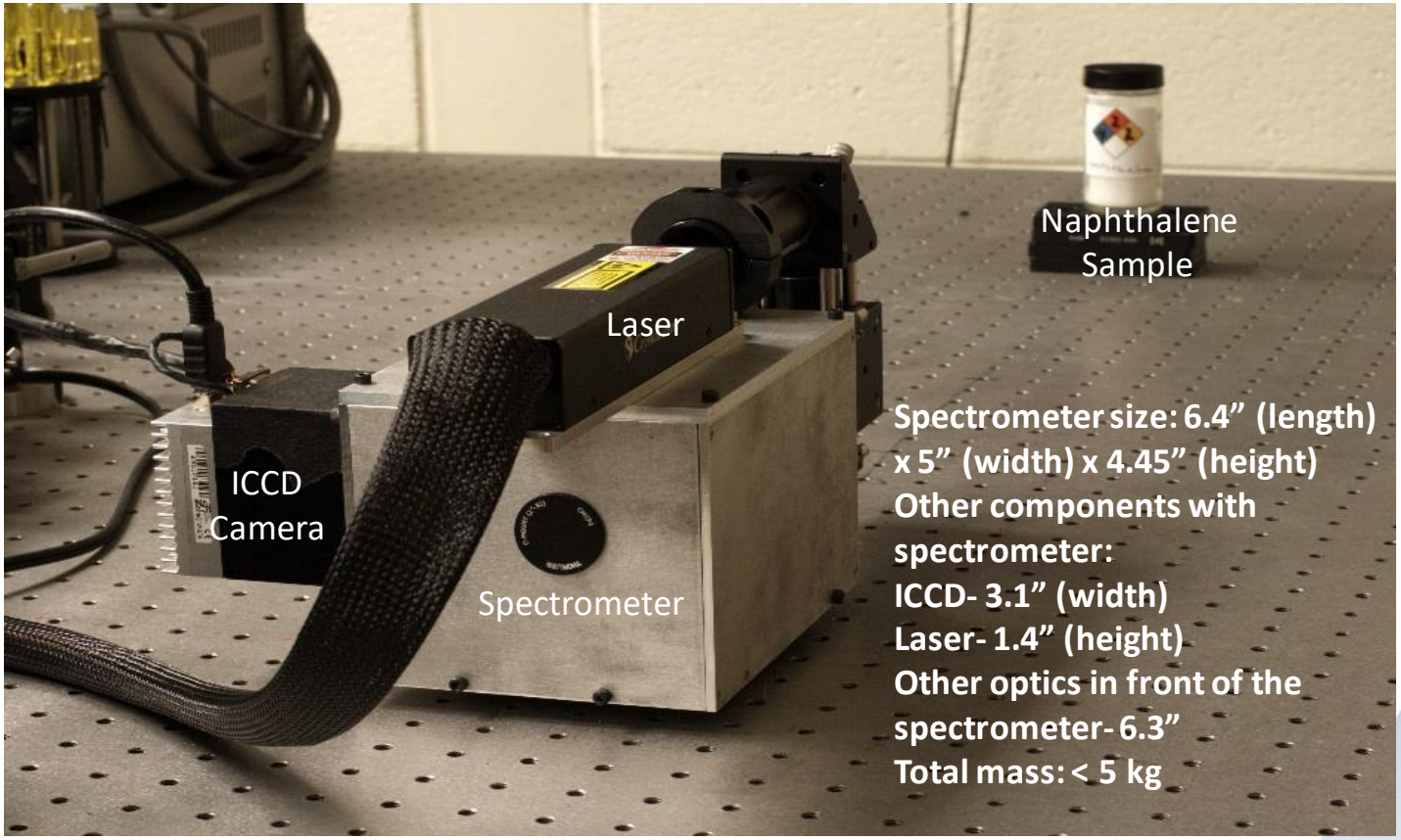
- Powerful technique for determining the composition and the structure of a solid, liquid, or gas material based on its vibrational spectra.
- Ideal for analyzing rocks, minerals, organic, and biological materials (e.g., tissues, cells), as well as amino acids because it produces spectra with very sharp peak, resulting in unambiguous detection.

Raman Scattering



Scattered radiation with shifted frequency provides information about the composition and molecular structure of the sample

Standoff Ultra-Compact μ-Raman Sensor System



Standoff Ultra-Compact μ-Raman Sensor System with a Laser, an ICCD camera, a grating, c-mount lenses and a slit inside spectrograph, and mounting optical components; and a target Naphthalene sample.

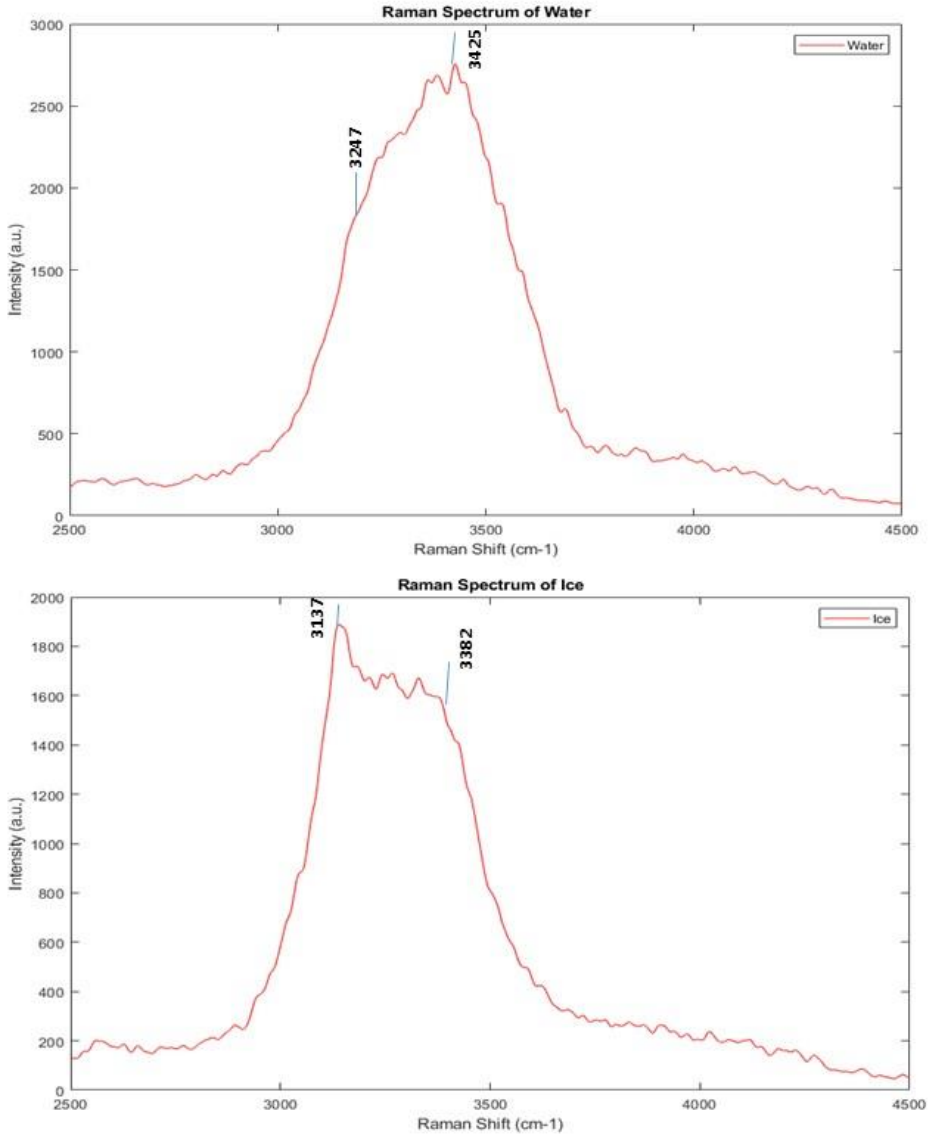
Standoff Ultra-Compact μ-Raman Sensor…

Sample Inspection and Identification

- Use Standoff μ-Raman sensor system to inspect and identify:
  - Water and Ice;
  - Calcite, Naphthalene, Sulfur, and Mixed Naphthalene/Sulfur;
  - Biomarkers (amino acids: L-Glutamine);
  - Synthetic Urine (Surine) sample;
  - Compare Surine with Human Urine sample.
- Utilize Raman spectroscopy to identify normal and abnormal breast tissues of a patient in Europe.

Standoff Ultra-Compact μ-Raman Sensor…

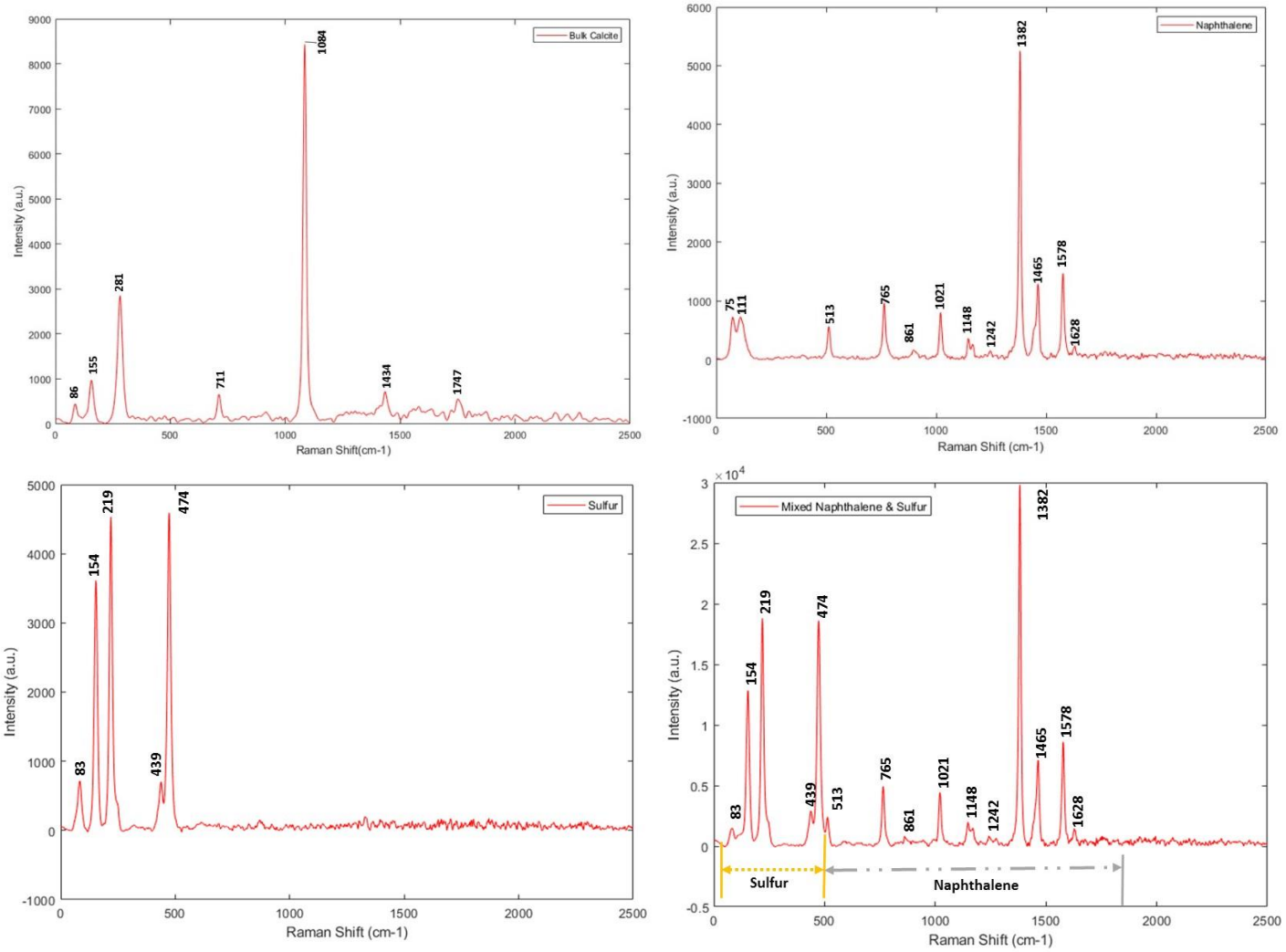
Raman spectrum of water and ice



Raman spectrum at high frequency region of water and ice obtained using a 532 nm pulsed laser with line shaped laser beam (10 μm width by 5 mm height) at a distance of 6 cm.

Standoff Ultra-Compact μ-Raman Sensor…

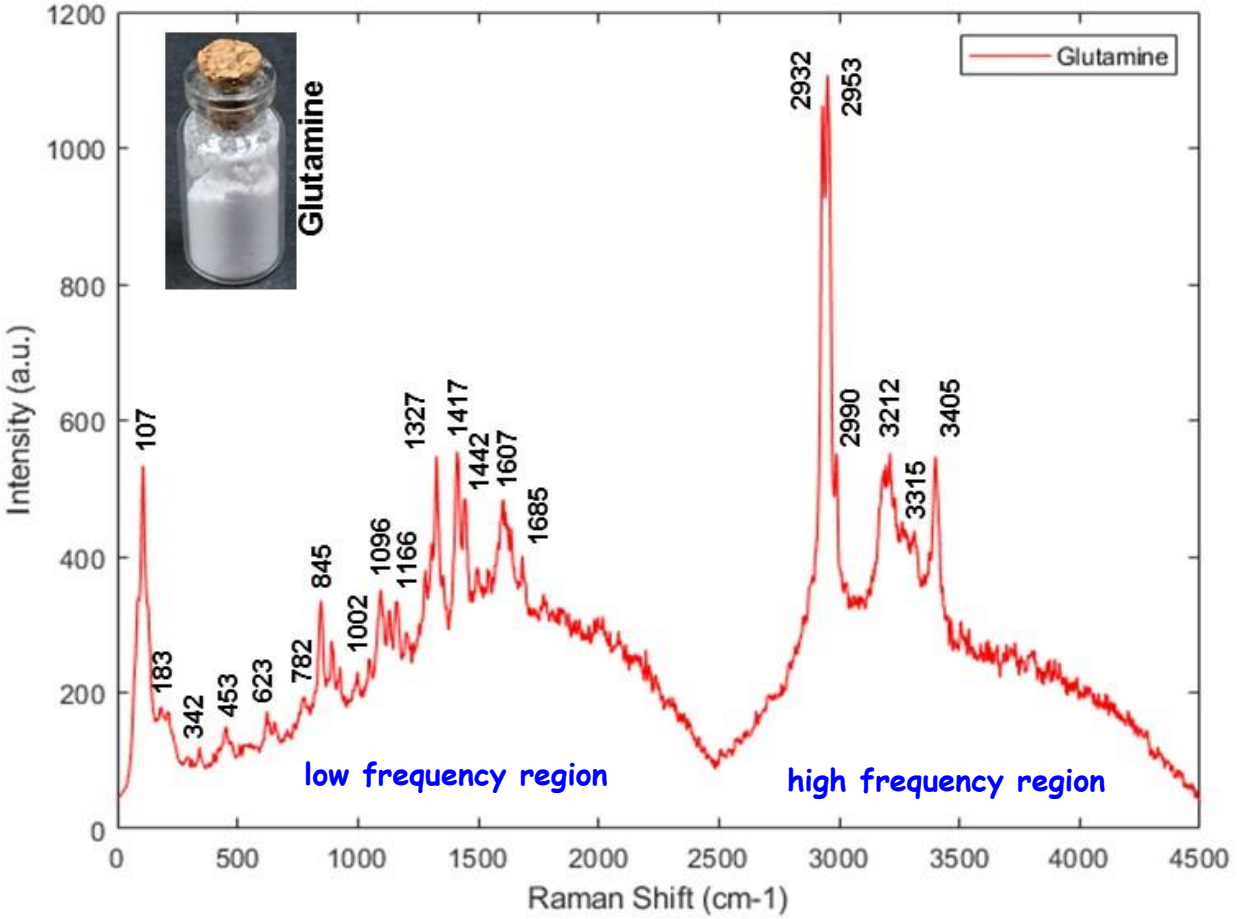
Raman Spectra of Calcite, Naphthalene, Sulfur, and Mixed Naphthalene/Sulfur



Sharp Raman peaks at low frequency region of calcite, naphthalene, sulfur, and mixed naphthalene/sulfur obtained using a 532 nm pulsed with a line shaped laser beam (10 μm width by 5 mm height) at a distance of 6 cm.

Standoff Ultra-Compact μ-Raman Sensor…

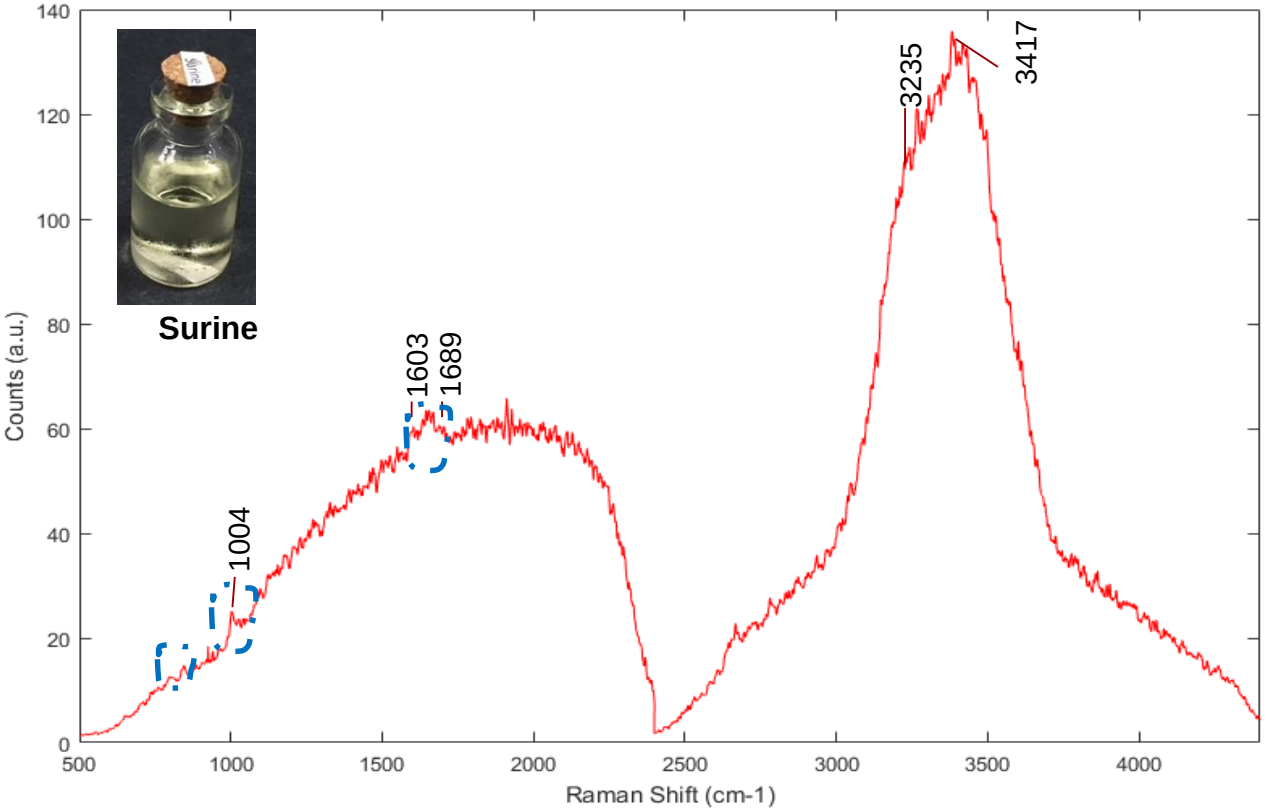
Raman Spectra of Amino Acid (L-Glutamine) at a distance of 6 cm



Sharp Raman peaks at low frequency (left) and high frequency (right) regions of L-glutamine obtained using a 532 nm pulsed laser with a line shaped laser beam (10 μm width by 5 mm height) at a distance of 6 cm.

Standoff Ultra-Compact μ-Raman Sensor…

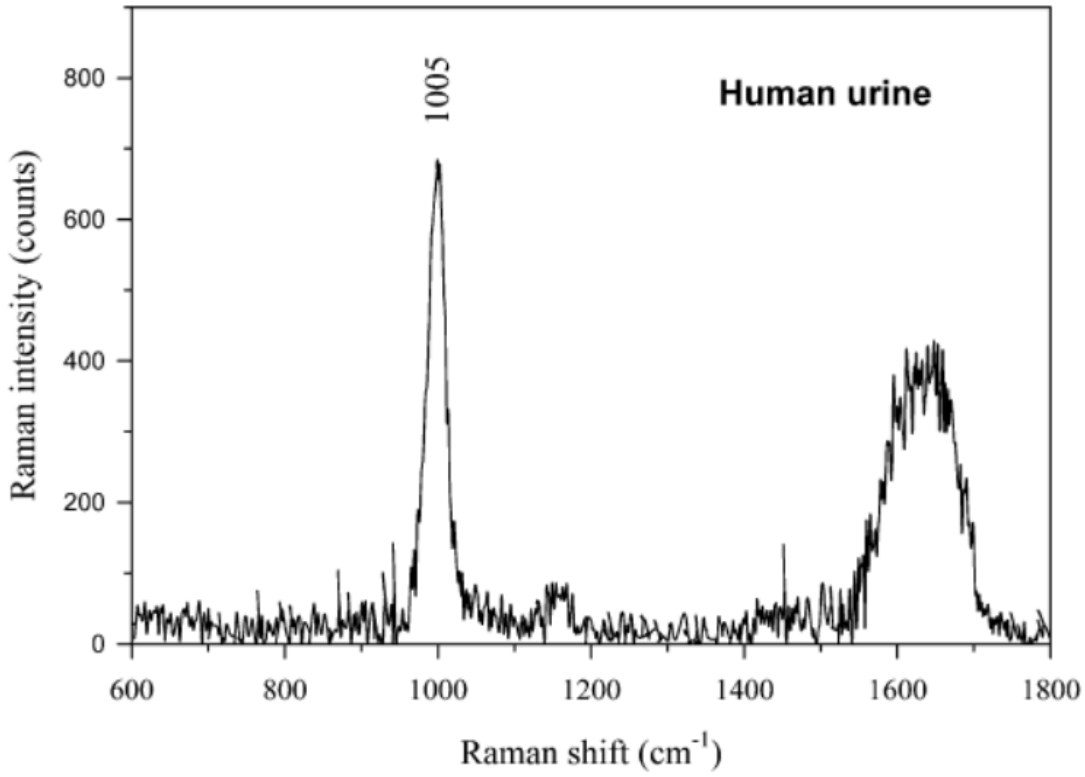
Raman spectra of Synthetic Urine using a 532 nm laser at 6 cm distance



A sharp peak at around 1004 cm-1 and broad peak from 1603 to 1689 cm-1 are due to the non-biological urine spectrum and 3235 to 3417 cm-1 band is due to H2O band.

Standoff Ultra-Compact μ-Raman Sensor…

Raman spectrum of Human Urine using 785 nm laser

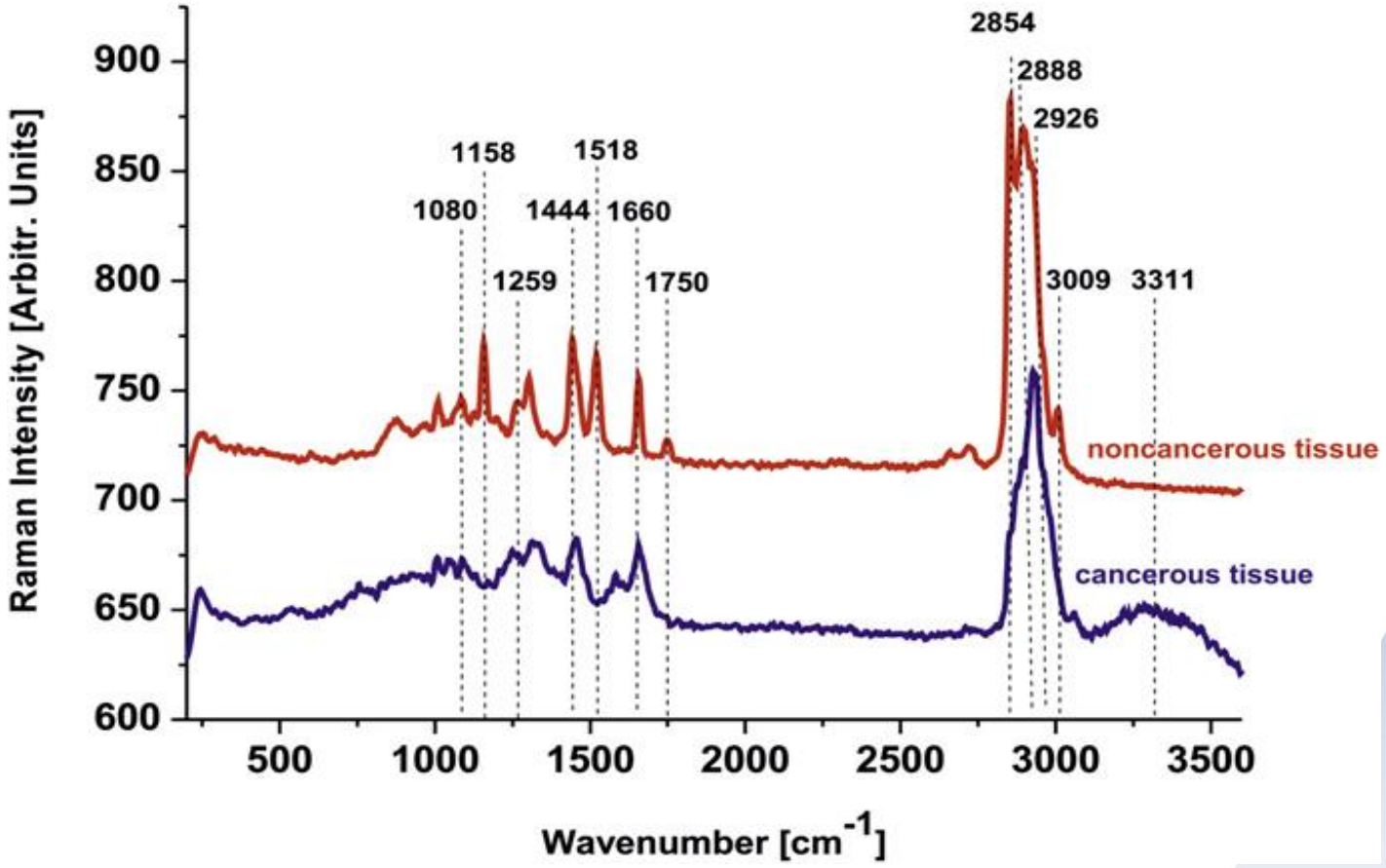


Raman spectrum of human urine.

A peak at 1005 cm-1 is due to ephedrine (urea) and a broadband around 1600 cm-1 is from urine. Courtesy: **Guimaraes, et al., Near Infrared Raman Spectroscopy (NIRS): A technique for doping control, Spectroscopy 20 (2006), 185-194, IOS Press.**

Standoff Ultra-Compact μ-Raman Sensor…

Raman Spectra of normal and abnormal Breast Tissues of a Patient



The Raman spectra of the noncancerous and cancerous (infiltrating ductal cancer) bulk breast tissue of a patient. (Courtesy: H. Abramczyk et. al., Raman 'Optical Biopsy' of human breast cancer, Prog. Biophys. and Mol. Biology 108, 74-81 (2012)).

Summary & Proposed Applications

- We demonstrated Raman spectra of water, ice, minerals, organics, biomarkers (amino acids: L-Phenylalanine, L-glutamine, L-glycine, L-Alanine, L-Arginine), and synthetic urine sample using a 532 nm pulsed laser with a 10 μm width by 5 mm height laser spot at 6 cm target distance.

- The SUCR sensor is one of the most advanced remote Raman instruments ever developed and would solve some of the limitations (requires dark condition, sample collection/ manipulation, and slow) of traditional micro-Raman systems.

- Finally, we propose to use this SUCR system as a hand-held instrument to inspect and identify Astronauts' specimens (blood, stool, urine, tumor tissue, or other tissues or bodily fluids) in daylight or nighttime at 6 to 20 cm target distance in space under NASA Human exploration missions to Moon and Mars.

Publications

Journal Publication & News Release (under partial supports from NASA HQ PICASSO & IRAD programs)

- M.N. Abedin, A.T. Bradley, A.K. Misra, Y. Bai, G.D. Hines, and S.K. Sharma, "Standoff ultra-compact μ-Raman sensor for planetary surface explorations," Applied Optics, 57 (1), 62-68 (2018).

- Based on Applied Optics Paper, editors of The Optical Society of America (OSA) published a News Release of "Powerful New Tool for Looking for Life Beyond Earth", which showed a large public interest in this technology.

Complimentary Letter:

- Received a letter from E. Nolan, Deputy Executive Director and Chief Publishing Officer from OSA about our published paper: " Standoff ultra-compact μ-Raman Sensor for Planetary Surface Explorations," in the Journal of Applied Optics (January Issue, 2018) that has reached a potential audience of at least 12.7 million within three weeks.

Patent:

- NASA LaRC filed a patent "Standoff Ultra-Compact micro-Raman Sensor" (under partial supports from NASA HQ PICASSO program) with NASA Langley Case # LAR 19274-1 to NASA on July 1, 2018.