

This **Heterodyne Interferometer** is used to measure the displacement Δx . In addition to the advantages mentioned in the main text, this interferometer contains fewer parts and can be fabricated with looser tolerances, relative to a typical prior interferometer designed for performing the same measurement.

and reference light beams pass through a beam splitter where the $f_0 + \delta f$ beam is superimposed upon them. Then by use of truncated mirrors and lenses, (1) the target signal and part of the $f_0 + \delta f$ signal are sent to one photodetector while (2) the reference signal and part of the $f_0 + \delta f$ signal are sent to another photodetector. The lowest-frequency components of the heterodyne outputs of the two photodetectors are signals of frequency δf , the difference between the phases of

which is proportional to the amount by which the length of the target path exceeds that of the reference path. Any displacement Δx , of the target along the optical path results in a proportional change in this phase difference. Hence, measurement of the phase difference and of any change in the phase difference yields information on the displacement. One can calculate the displacement by use of the equation

$$\Delta x = \lambda \Delta \phi / 4\pi,$$

where λ is the wavelength of the laser

light and $\Delta \phi$ is the change in the phase difference.

This work was done by Feng Zhao of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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UV-Enhanced IR Raman System for Identifying Biohazards

UV pumping would increase IR Raman emissions.

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An instrumentation system that would include an ultraviolet (UV) laser or light-emitting diode, an infrared (IR) laser, and the equivalent of an IR Raman spectrometer has been proposed to enable noncontact identification of hazardous biological agents and chemicals. In prior research, IR Raman scattering had shown promise as a means of such identification, except that the Raman-scattered

light was often found to be too weak to be detected or to enable unambiguous identification in practical applications. The proposed system (see Figure 1) would utilize UV illumination as part of a two-level optical-pumping scheme to intensify the Raman signal sufficiently to enable positive identification.

The UV and IR lasers would share common reflective optics and would il-

luminate a target simultaneously. The spectrum of IR Raman-scattered light emitted by the target would be characteristic of the target material and could therefore be used to identify the material, provided that the Raman signal was strong enough. The Raman-scattered IR light from the target would be collected and directed through a wavelength-dispersive optical element or,

optionally, through a set of narrow-band filters designed to pass only the Raman wavelengths characteristic of the biological agent(s) or chemical(s) of interest. The spectrally dispersed or filtered light would then strike photodetectors, the outputs of which would be processed to obtain the Raman spectrum or equivalent identifying information. The signal-to-noise ratio of the Raman signal, and hence the effective sensitivity for identification, could be increased by pulsing (in contradistinction to steady-state operation) of the lasers in conjunction with synchronous detection (lock-in amplification) of the photodetector outputs, phase locking, and/or chopping of the light impinging on the photodetectors. The UV pulse emission time would envelop the on-time of the IR excitation pulse. Since the two-pulse set could be independently lengthened, thus shortening time delay to the rising edge of the UV pulse, specific enhancements of the signal-to-noise are possible for a given target material. Thus by tuning the pulse durations and timing offsets, optimal separation of the fluorescence background signal from the Raman signal may be achieved.

A brief description of Rayleigh and Raman scattering is prerequisite to a meaningful description of the principle of the two-level optical-pumping scheme that would be exploited in the proposed system to enhance the Raman signal. Most of the IR light incident upon the target would be Rayleigh-scattered: that is, it would be scattered at the same wavelength as that of the incident IR laser beam because most of the vibrating electrons in the target molecules of interest would relax back to their ground states. A small proportion of all incident photons (of the order of one in a million) would be Raman-scattered: This means that they would be scattered at wavelengths slightly greater than that of the incident IR beam because some of the electrons would relax to vibrational states slightly above the ground state.

The pumping scheme is depicted schematically in Figure 2. The UV laser would pump electrons from the ground state to quantum state 1. The IR laser would further pump the electrons from quantum state 1 to quantum state 2. The electrons would then decay from state 2 by Raman and Rayleigh scattering. The instrument would still work if there were no UV laser because there would be a small

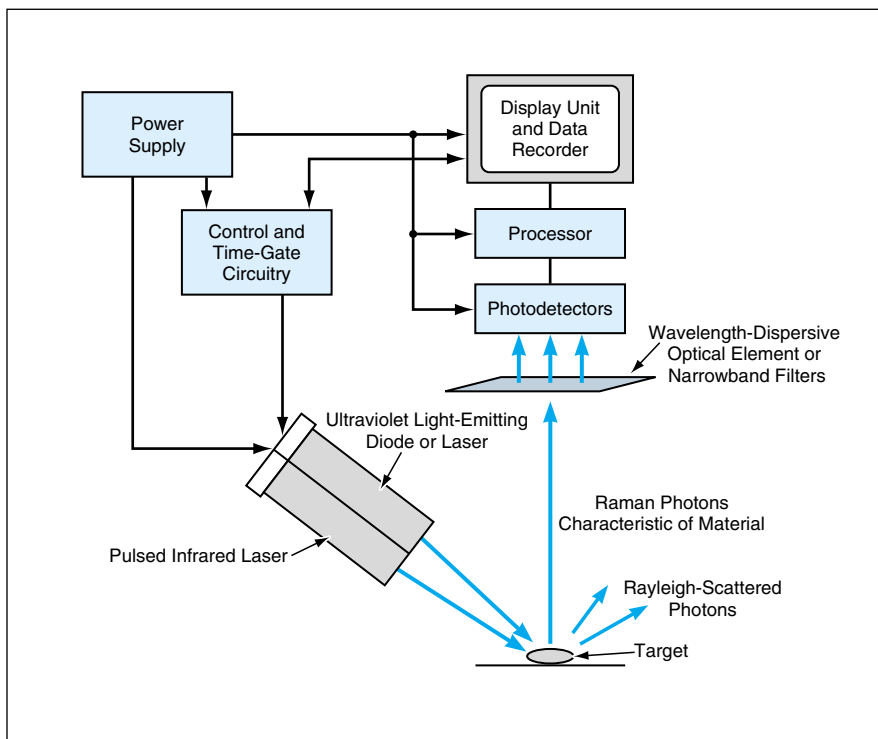


Figure 1. This **Instrumentation System** would induce and measure IR Raman scattering to identify a hazardous material by means of its characteristic Raman-scattering spectrum.

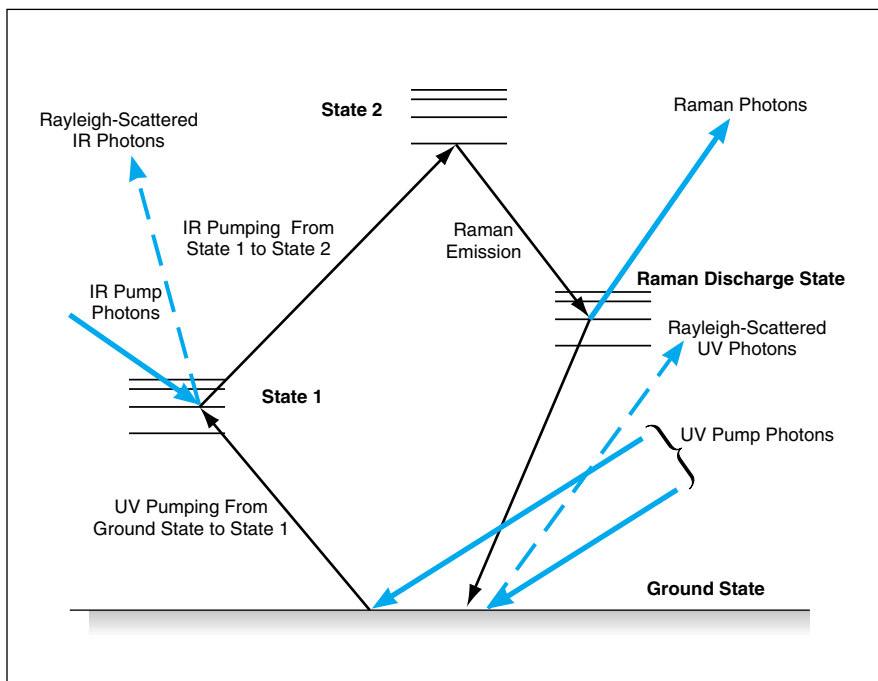


Figure 2. **Two-Level Optical Pumping** by the UV and IR lasers would result in a Raman signal more intense than that obtained by illuminating the target with the IR laser alone.

natural population of electrons in state 1. The role of the UV laser would be simply to increase the population in state 1, thereby making more electrons available for pumping to state 2, thereby further increasing the number of Raman-scattered photons emitted in the decay from state 2.

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