

second order Zeeman shift can be made to almost exactly cancel the residual second-order Doppler shift.

In an experimental implementation of this scheme, a 5-turn compensation coil was placed between the quadrupole and 12-pole traps and was excited

with a current of 3 mA. With this compensation scheme, the measured fractional frequency stability of the second-order Doppler shift is 3×10^{-17} . As a result, all systematics in the clock, and the clock itself, should have a long-term stability of better than 5×10^{-17} ,

which would be the best ever measured in any clock.

This work was done by Eric Burt and Robert Tjoelker of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov NPO-43199

Nanostructures Exploit Hybrid-Polariton Resonances

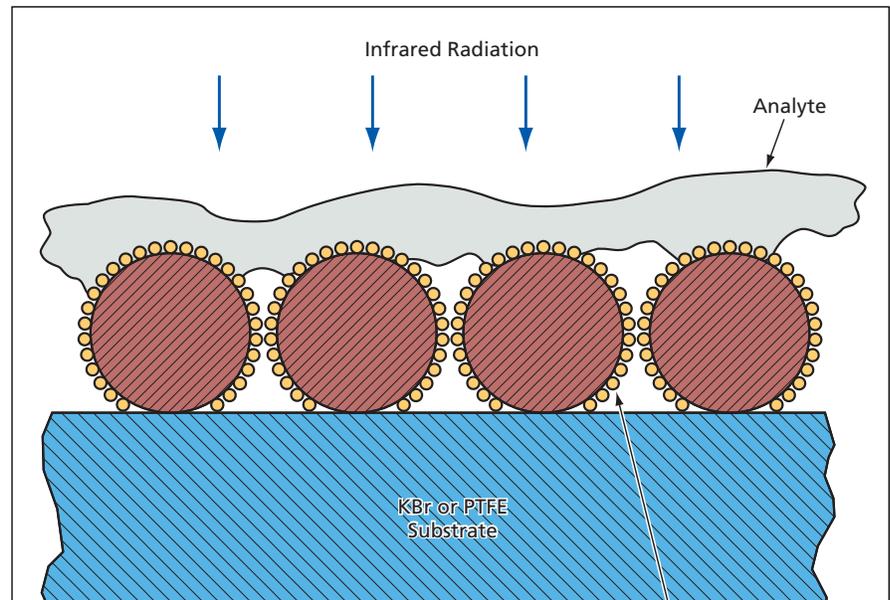
Infrared absorption or scattering by molecules of interest can be greatly enhanced.

NASA's Jet Propulsion Laboratory, Pasadena, California

Nanostructured devices that exploit the hybrid-polariton resonances arising from coupling among photons, phonons, and plasmons are subjects of research directed toward the development of infrared-spectroscopic sensors for measuring extremely small quantities of molecules of interest. The spectroscopic techniques in question are surface enhanced Raman scattering (SERS) and surface enhanced infrared absorption (SEIRA). An important intermediate goal of this research is to increase the sensitivity achievable by these techniques. The basic idea of the approach being followed in this research is to engineer nanostructured devices and thereby engineer their hybrid-polariton resonances to concentrate infrared radiation incident upon their surfaces in such a manner as to increase the absorption of the radiation for SEIRA and measure the frequency shifts of surface vibrational modes.

The underlying hybrid-polariton-resonance concept is best described by reference to experimental devices that have been built and tested to demonstrate the concept. The nanostructure of each such device includes a matrix of silicon carbide particles of approximately 1 micron in diameter that are supported on a potassium bromide (KBr) or poly(tetrafluoroethylene) [PTFE] window. These grains are sputter-coated with gold grains of 40-nm size (see figure).

From the perspective of classical electrodynamics, in this nanostructure, that includes a particulate or otherwise rough surface, the electric-field portion of an incident electromagnetic field becomes concentrated on the particles when optical resonance conditions are met. Going beyond the perspective of classical electrodynamics, it can be seen that when the resonance frequencies of surface phonons and surface plasmons overlap, the coupling of the resonances



Circumferential Belts were formed by diamond turning on the initially cylindrical surface of a CaF₂ rod. The radial depths and axial widths of the belts were chosen to make some of the belts act as single-mode and some as multi-mode WGM resonators.

gives rise to an enhanced radiation-absorption or -scattering mechanism.

The sizes, shapes, and aggregation of the particles determine the frequencies of the resonances. Hence, the task of designing a nanostructure to exhibit the desired radiation-absorption properties translates, in large part, to selecting particle sizes and shapes to obtain the desired enhanced coupling of energy from photons to plasmons and phonons. To broaden the spectral region(s) of enhanced absorption, one would select a distribution of particle sizes and shapes.

In a test, the infrared spectra of one of the experimental nanostructures described above were measured before and after the nanostructure was coated with an approximately-monomolecular-thickness layer of poly(methyl methacrylate) [PMMA]. Among other things, the measurements showed that in the af-

fect wavelength range, in the presence of the nanostructure, the magnitude of absorption by the thin PMMA film was comparable to the absorption by a considerably thicker PMMA film without the nanostructure.

This work was done by Mark Anderson of Caltech for NASA's Jet Propulsion Laboratory.

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*Innovative Technology Assets Management
JPL*

*Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240*

E-mail: iaoffice@jpl.nasa.gov

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