

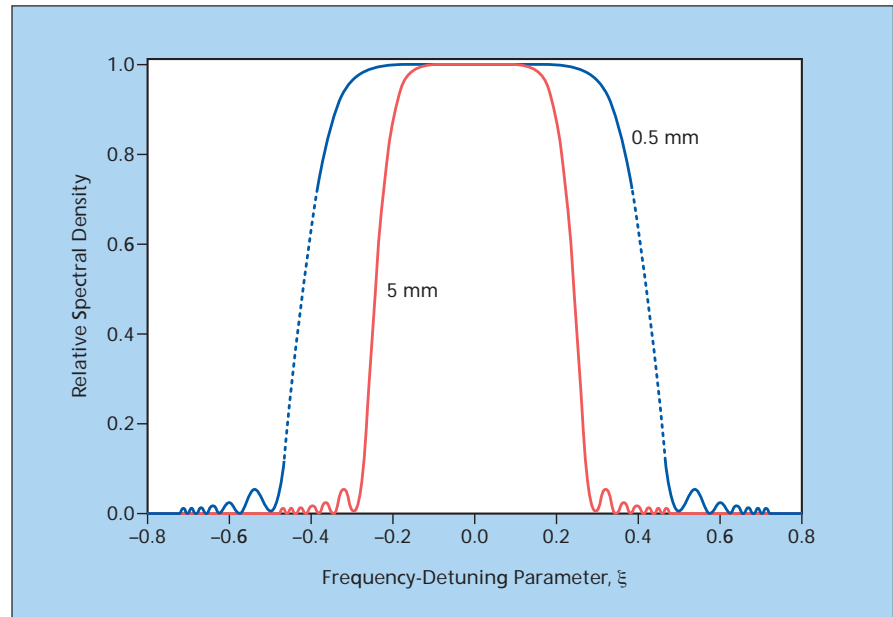
Ultra-Broad-Band Optical Parametric Amplifier or Oscillator

Potential applications include wavelength-multiplexing communications and generating reference frequencies.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for an ultra-broad-band optical parametric amplifier or oscillator has emerged as a by-product of a theoretical study in fundamental quantum optics. The study was originally intended to address the question of whether the two-photon temporal correlation function of light [in particular, light produced by spontaneous parametric down conversion (SPDC)] can be considerably narrower than the inverse of the spectral width (bandwidth) of the light. The answer to the question was found to be negative. More specifically, on the basis of the universal integral relations between the quantum two-photon temporal correlation and the classical spectrum of light, it was found that the lower limit of two-photon correlation time is set approximately by the inverse of the bandwidth. The mathematical solution for the minimum two-photon correlation time also provides the minimum relative frequency dispersion of the down-converted light components; in turn, the minimum relative frequency dispersion translates to the maximum bandwidth, which is important for the design of an ultra-broad-band optical parametric oscillator or amplifier.

In the study, results of an analysis of the general integral relations were applied in the case of an optically nonlinear, frequency-dispersive crystal in which SPDC produces collinear photons. Equations were found for the crystal orientation and pump wavelength, specific for each parametric-down-converting crystal, that eliminate the relative frequency dispersion of collinear degenerate (equal-frequency) signal and idler components up to the fourth order in the frequency-detuning parameter, ξ . [The degenerate frequency, ν_0 , of the signal or idler component is half the pump frequency. If the difference between the signal or pump component and the degenerate frequency is ν (in which case the corresponding difference for the pump or signal component, respectively, is $-\nu$), then $\xi \equiv \nu/\nu_0$.]



The Relative Spectral Density in SPDC was calculated for a suitably oriented pump beam in 5- and 0.5-mm-long BeSO₄ crystals for a degenerate wavelength of 923.8 nm.

As a result of the elimination of the relative frequency dispersion up to fourth order, an optical parametric amplifier consisting of such a crystal at the specified orientation and pumped at the specified wavelength can be designed to exhibit a relatively flat spectral-density-versus-frequency curve over more than an octave (see figure). Conveniently, the octave could be chosen to

include two wavelength bands — centered at 1,330 and 1,560 nm — that are used in optical communications. Hence, for example, the amplifier might be useful in a wavelength-multiplexing communication system using these two wavelength bands. In another potential application, by configuring this amplifier as a mode-locked oscillator, one could obtain a self-locked comblike spectrum that could serve as an excellent set of frequency references.

This work was done by Dmitry Strelkov, Andrey Matsko, Anatoly Savchenkov, and Lute Maleki of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-41584

Particle-Image Velocimeter Having Large Depth of Field

This instrument could be used to monitor particle-laden flows.

Goddard Space Flight Center, Greenbelt, Maryland

An instrument that functions mainly as a particle-image velocimeter provides data on the sizes and velocities of flying opaque particles. The instrument is being developed as a means of characterizing fluxes of wind-borne dust particles

in the Martian atmosphere. The instrument could also be adapted to terrestrial use in measuring sizes and velocities of opaque particles carried by natural winds and industrial gases. Examples of potential terrestrial applications include moni-

toring of airborne industrial pollutants and airborne particles in mine shafts.

The design of this instrument reflects an observation, made in field research, that airborne dust particles derived from soil and rock are opaque enough to be

observable by use of bright field illumination with high contrast for highly accurate measurements of sizes and shapes. The instrument includes a source of collimated light coupled to an afocal beam expander and an imaging array of photodetectors. When dust particles travel through the collimated beam, they cast shadows. The shadows are magnified by the beam expander and relayed to the array of photodetectors.

Inasmuch as the images captured by the array are of dust-particle shadows rather than of the particles themselves, the depth of field of the instrument can be large: the instrument has a depth of field of about 11 mm, which is larger than the depths of field of prior particle-image velocimeters. The instrument can resolve, and measure the sizes and velocities of, particles having sizes in the approximate range of 1 to 300 μm .

For slowly moving particles, data from two image frames are used to calculate velocities. For rapidly moving particles, image smear lengths from a single frame are used in conjunction with particle-size measurement data to determine velocities.

This work was done by Brent Bos of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15230-1

Enhancing SERS by Means of Supramolecular Charge Transfer

Sensors based on this method could detect chemical and biological hazards.

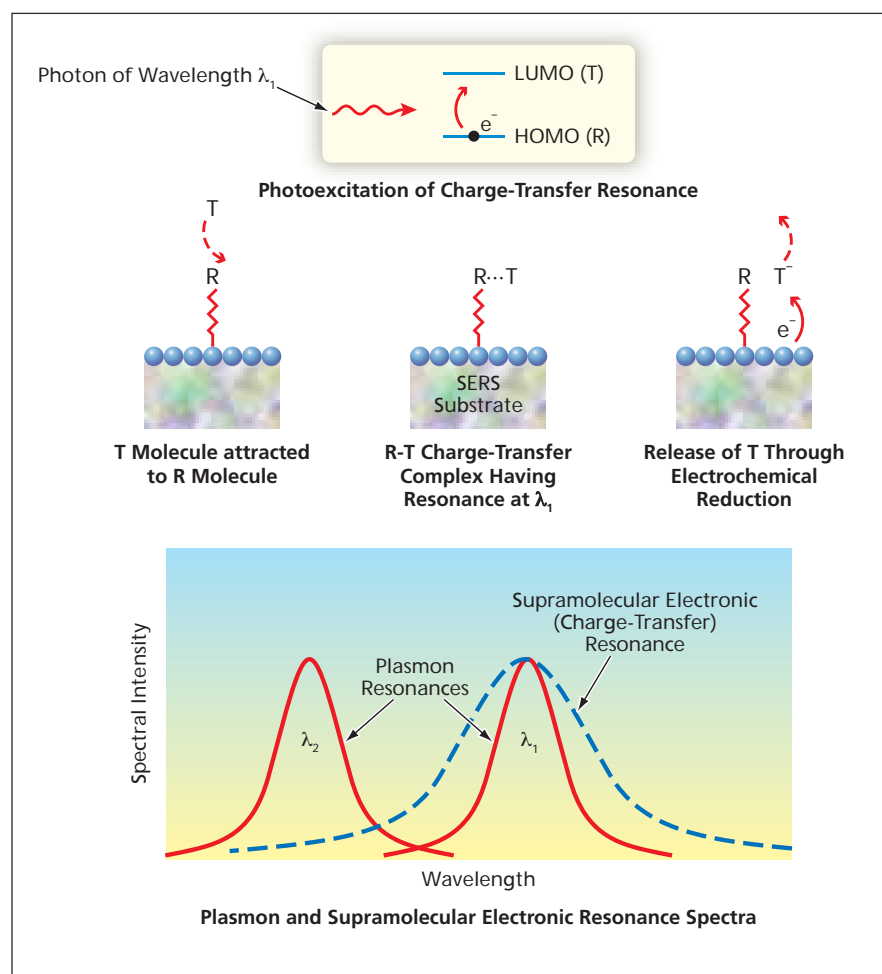
NASA's Jet Propulsion Laboratory, Pasadena, California

In a proposed method of sensing small quantities of molecules of interest, surface enhanced Raman scattering (SERS) spectroscopy would be further enhanced by means of intermolecular or supramolecular charge transfer. There is a very large potential market for sensors based on this method for rapid detection of chemical and biological hazards.

In SERS, the Raman signals (vibrational spectra) of target molecules become enhanced by factors of the order of 10^8 when those molecules are in the vicinities of nanostructured substrate surfaces that have been engineered to have plasmon resonances that enhance local electric fields. SERS, as reported in several prior *NASA Tech Briefs* articles and elsewhere, has remained a research tool and has not yet been developed into a practical technique for sensing of target molecules: this is because the short range (5 to 20 nm) of the field enhancement necessitates engineering of receptor molecules to attract target molecules to the nanostructured substrate surfaces and to enable reliable identification of the target molecules in the presence of interferants.

Intermolecular charge-transfer complexes have been used in fluorescence-, photoluminescence-, and electrochemistry-based techniques for sensing target molecules, but, until now, have not been considered for use in SERS-based sensing. The basic idea of the proposed method is to engineer receptor molecules that would be attached to nanostructured SERS substrates and that would interact with the target molecules to form receptor-target supramolecular charge-transfer complexes wherein the charge transfer could be photoexcited.

As shown schematically in the figure,



A Target Molecule Would Become Bound to a receptor molecule on an SERS substrate. The resulting R-T complex would have a charge-transfer energy band that would coincide with a plasmon resonance, λ_1 , of the substrate. Optionally, the target molecule could be released through electrochemical reduction.

a SERS substrate would be functionalized with a receptor (R) molecule that has an affinity for a target (T) molecule. The receptor molecule could be designed so that the lowest unoccupied

molecular orbital (LUMO) of the target molecule would lie above the highest occupied molecular orbital (HOMO) of the target molecule by an energy difference that would correspond to one of