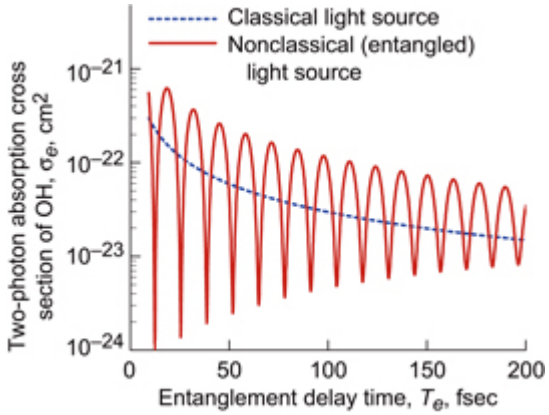
Quantum Sensing and Communications Being Developed for Nanotechnology

An interdisciplinary quantum communications and sensing research effort for application in microdevices has been underway at the NASA Glenn Research Center since 2000. Researchers in Glenn's Instrumentation and Controls, Communications Technology, and Propulsion and Turbomachinery Divisions have been working together to study and develop techniques that utilize quantum effects for sensing and communications. The emerging technology provides an innovative way to communicate faster and farther using less power and to sense, measure, and image environmental properties in ways that are not possible with existing technology.

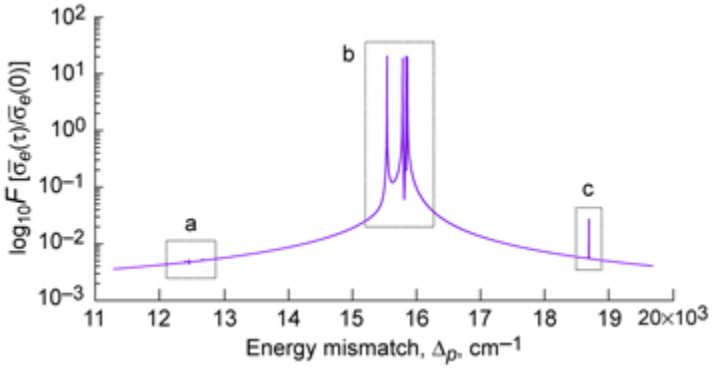
The Quantum Sensing and Communications team has completed initial tests of an optical communications system for low-radiated-power communications. Information has been optically transmitted over 1 meter of free space in an optically noisy environment. The information was carried in about 10,000 photons/sec, or about 3 femtowatts (10^{-15} W) of radiated optical power, at a frequency of 1 kHz. This amounts to 3 attowatts (10^{-18} W) of radiated power per bit of information: one of the lowest power tests of information transfer over free space in a noisy environment known. This technology could solve the ongoing problem of how to communicate with, or otherwise extract information from, a nanoscale electromechanical systems (NEMS) device. This testbed will be used in the future to develop optical communications protocols and components applicable for nanorobots.



Two-photon absorption cross section of OH (A-X) as a function of the entanglement delay time (solid line). The classical two-photon cross section (dashed line) exhibits monotonic behavior. The non-monotonic variation in the absorption cross-section can be used to extract virtual-state energy-level information.

An example of ongoing quantum sensing work that is part of this project is a theoretical study where entangled photon virtual-state spectroscopy is applied to a molecular system for the first time (ref. 1). Entangled two-photon spectroscopy is a new technique that will permit ultra-high-sensitivity measurements of molecular properties with very little optical

power (attowatts). This technique has applications, for example, in two-photon fluorescence confocal microscopy because it greatly reduces the optical power needed to avoid optical damage to the specimen being probed. This work demonstrates that the two-photon absorption cross section of the hydroxyl radical (OH) induced by the entangled photons is non-monotonic as a function of entanglement delay time, as shown in the preceding graph. Taking the Fourier transform of the data in the left graph allows one to probe the virtual-state energy eigenvalues of OH in energy or frequency space, as shown in the following graph. Thus, one can use a fixed laser excitation energy to produce an energy spectrum. That is, an energy spectrum can be obtained without scanning the laser wavelength. This analysis reveals fundamental requirements and limitations in this new spectroscopic technique such as the requirement that the relative path delay be varied over a picosecond (10^{-12} sec) range with a femtosecond (10^{-15} sec) resolution.



Fourier transform of the two-photon absorption cross-section of OH (A-X) reveals the virtual-state energy spectrum. The virtual states can be seen in the peaks highlighted by the three enclosed boxes (labeled a, b, and c). Virtual states of a molecule show the actual transition path taken by the molecule after it has absorbed the first photon, but before it has absorbed the second photon. These virtual states are impossible to observe using conventional, nonentangled photons. $A^2\varepsilon^+ - X^2\pi$; electronic transition of OH.

Reference

1. Kojima, Jun; and Nguyen, Quang-Viet: Entangled Biphoton Virtual State Spectroscopy of the $A^2e^+ - X^2\varepsilon$ System of OH. Chem. Phys. Lett., vol. 396, 2004, pp. 323–328.

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