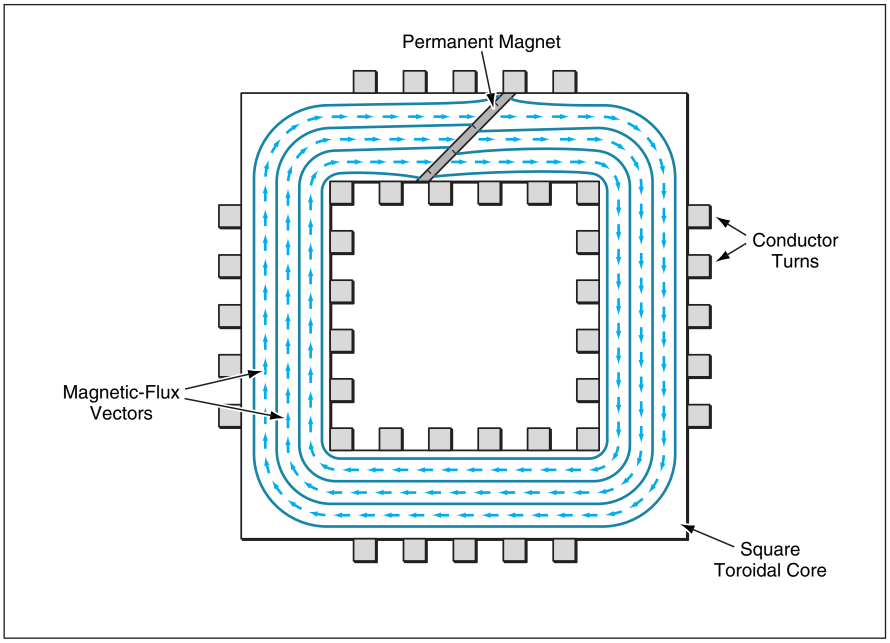


A **Permanent Magnet Would Be Placed in a Gap** in the toroidal ferromagnetic core of a microinductor. Slanting of the gap as shown here is a design option that would make it possible to use a larger permanent magnet to increase the permanent magnetic flux, without incurring a need for pole pieces to concentrate the permanent magnetic flux into the core.

pressed by several equations based on the traditional magnetic-circuit approximation. The equations involve the core and gap dimensions and the magnetic-property parameters of the core and magnet materials.

The equations show that, other things remaining equal, as the maximum current is increased, one must increase the size of the core to prevent the flux density from rising to the saturation level. By using a permanent bias flux to oppose the flux generated by the DC component of the current, one would reduce the net DC component of flux in the core, making it possible to reduce the core size needed to prevent the total flux density (sum of DC and AC components) from rising to the saturation level. Alternatively, one could take advantage of the reduction of the net DC component of flux by increasing the allowable AC component of flux and the corresponding AC component of current. In either case, permanent-magnet material and the slant (if any) and thickness of the gap must be chosen according to the equations to obtain the required bias flux.

In modifying the design of the inductor, one must ensure that the inductance is not altered. The simplest way to preserve the original value of inductance would be to leave the gap dimensions unchanged and fill the gap with a permanent-magnet material that, fortuitously, would produce just the required bias flux. A more generally applicable alternative would be to partly fill either the original gap or a slightly enlarged gap with a suitable permanent-magnet material (thereby leaving a small residual gap) so that the reluctance of the resulting magnetic circuit would yield the desired inductance.

This work was done by Udo Lieneweg and Brent Blaes of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-21102

Using Correlated Photons To Suppress Background Noise

Optical communication signals could be detected against very bright backgrounds.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of suppressing the effect of background noise in an optical communication system would exploit the transmission and reception of correlated photons at the receiver. The method would not afford any advantage in a system in which performance is limited by shot noise. However, if the performance of the system is limited by background noise (e.g., sunlight in the case of a free-space optical communication system or incoherently scattered in-band photons in the case of a fiber-optic communication system), then the proposed method could offer an advantage: the proposed method would make it possible to achieve a signal-to-noise ratio (S/N) significantly greater than that of an otherwise equivalent background-noise-limited optical communication system based on the classical transmission and reception of uncorrelated photons.

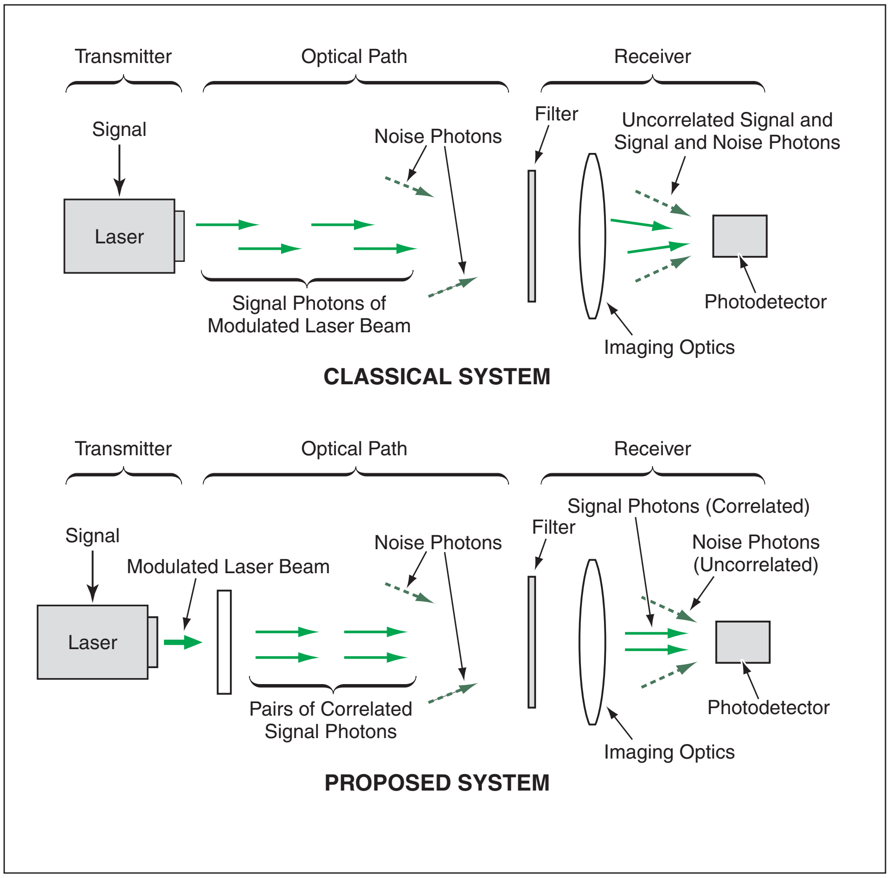
The figure schematically depicts a classical optical-communication system and a system according to the proposed method. In the classical system, a modulated laser beam is transmitted along an optical path to a receiver, the optics of which include a narrow-band-pass filter that suppresses some of the background noise. A photodetector in the receiver detects the laser-beam and background photons, most or all of which are uncorrelated.

In the proposed system, correlated photons would be generated at the transmitter by making a modulated laser beam pass through a nonlinear parametric down-conversion crystal. The sum of frequencies of the correlated photons in each pair would equal the frequency of the incident photon from which they were generated. As in the classical system, the correlated photons would travel along an optical path to a receiver, where they would be band-pass filtered and detected. Unlike in the classical system, the photodetector in the receiver in this system would be one that intrinsically favors the detection of pairs of correlated photons over the detection of uncorrelated photons. Even though there would be no way of knowing the precise location and time of creation of a given pair of correlated signal photons in the nonlinear down-conversion crystal, the fact that the photons are necessarily created at the same time and place makes it possible to utilize conventional geometrical imaging optics to reunite the photons in coincidence in the receiving photodetector.

Because most or all of the signal photons would be correlated while most or all of the noise photons would be uncorrelated, the S/N would be correspondingly enhanced in the photodetector output. An additional advantage to be gained by use of a correlated-photon detector is that it could be capable of recovering the signal even in the presence of background light so bright that a classical uncorrelated-photon detector would be saturated.

A blocked-impurity-band (BIB) photodetector that preferentially detects pairs of correlated photons over uncorrelated ones and that operates at a quantum efficiency of 88 percent is commercially available. This detector must be cooled to the temperature of liquid helium to obtain the desired low-noise performance. It is planned to use this detector in a proof-of-principle demonstration. In addition, it may be possible to develop GaN-based photodetectors that could offer the desired low-noise performance at room temperature.

This work was done by Deborah Jackson, George Hockney, and Jonathan Dowling of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30633



Pairs of Correlated Photons would be generated at the transmitter and preferentially detected at the receiver in the proposed system.

Atmospheric-Fade-Tolerant Tracking and Pointing in Wireless Optical Communication

Tracking is maintained through beacon signal fades.

NASA's Jet Propulsion Laboratory, Pasadena, California

An acquisition, tracking, and pointing (ATP) system, under development at the time of reporting the information for this article, is intended to enable a terminal in a free-space optical communication system to continue to aim its transmitting laser beam toward a receiver at a remote terminal when the laser beacon signal from the remote terminal temporarily fades or drops out of sight altogether. Such fades and dropouts can be caused by adverse atmospheric conditions (e.g., rain or clouds). They can also occur when intervening objects block the line of sight between terminals as a result of motions of those objects or of either or both terminals.

A typical prior ATP system in an optical-communication terminal, shown in the upper part of the figure, includes a retroreflector, a beam splitter, and a charge-coupled-device (CCD) image detector mounted on the same platform that holds the transmitting laser. With help of the beam splitter and the retroreflector, the direction of aim of the laser beam, relative to the direction to the beacon, is measured in terms of the relative positions of the beacon and a sample of the laser beam on the CCD. Hence, the CCD output constitutes an indication of the instantaneous aim of the transmitted laser beam and can be used as a feedback control signal for a steering mirror to point the transmitted laser beam toward the beacon. The CCD output is sampled at a high update rate to provide feedback compensation for any motion (including microscopic vibration) of the platform. If the intensity of the beacon signal reaching the CCD is reduced, the beam-pointing performance is reduced. If the reduction is severe or prolonged, the transmitted laser beam may cease to track the beacon, with consequent loss of the communication link.

The developmental ATP system, shown in the lower part of the figure, includes all the components of the prior system, plus an inertial sensor, which measures the vibrations and other motions of the platform. The feedback control subsystem utilizes the inertial-sensor output, in addition to the CCD output, as a source of feedback for control of the steering mirror: The inertial signal serves as an approximate indication of the instantaneous orientation of the