Electro-Optic Time-to-Space Converter for Optical Detector Jitter Mitigation

The ability to more precisely measure the arrival time of an optical pulse is valuable in free space optical communications, lidar, and quantum key distribution.

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A common problem in optical detection is determining the arrival time of a weak optical pulse that may comprise only one to a few photons. Currently, this problem is solved by using a photodetector to convert the optical signal to an electronic signal. The timing of the electrical signal is used to infer the timing of the optical pulse, but error is introduced by random delay between the absorption of the optical pulse and the creation of the electrical one. To eliminate this error, a time-to-space converter separates a sequence of optical pulses and sends them to different photodetectors, depending on their arrival time.

The random delay, called jitter, is at least 20 picoseconds for the best detectors capable of detecting the weakest optical pulses, a single photon, and can be as great as 500 picoseconds. This limits the resolution with which the timing of the optical pulse can be measured.

The time-to-space converter overcomes this limitation. Generally, the time-to-space converter imparts a time-dependent momentum shift to the incoming optical pulses, followed by an optical system that separates photons of different momenta. As an example, an electro-optic phase modulator can be used to apply longitudinal momentum changes (frequency changes) that vary in time, followed by an optical spectrometer (such as a diffraction grating), which separates photons with different momenta into different paths and directs them to impinge upon an array of photodetectors. The pulse arrival time is then inferred by measuring which photodetector receives the pulse.

The use of a time-to-space converter mitigates detector jitter and improves the resolution with which the timing of an optical pulse is determined. Also, the application of the converter enables the demodulation of a pulse position modulated signal (PPM) at higher bandwidths than using previous photodetector technology. This allows the creation of a receiver for a communication system with high bandwidth and high bits/photon efficiency.

This work was done by Kevin Birnbaum and William Farr of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45799

Partially Transparent Petaled Mask/Occulter for Visible-Range Spectrum

The intensity along the optical axis can be suppressed up to ten orders of magnitude.

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The presence of the Poisson Spot, also known as the spot of Arago, has been known since the 18th century. This spot is the consequence of constructive interference of light diffracted by the edge of the obstacle where the central position can be determined by symmetry of the object. More recently, many NASA missions require the suppression of this spot in the visible range. For instance, the exoplanetary missions involving space telescopes require telescopes to image the planetary bodies orbiting central stars. For this purpose, the starlight needs to be suppressed by several orders of magnitude in order to image the reflected light from the orbiting planet. For the Earth-like planets, this suppression needs to be at least ten orders of magnitude. One of the common methods of suppression involves sharp binary petaled occulters envisioned to be placed many thousands of miles away from the telescope blocking the starlight.

The suppression of the Poisson Spot by binary sharp petal tips can be problematic when the thickness of the tips becomes smaller than the wavelength of the incident beam. First they are difficult to manufacture and also it invalidates the laws of physical optics. The proposed partially transparent petaled masks/occulters compensate for this sharpness with transparency along the surface of the petals. Depending on the geometry of the problem, this transparency can be customized such that only a small region of the petal is transparent and the remaining of the surface is opaque. This feature allows easy fabrication of this type of occultation device either as a mask or occulter.

A partially transparent petaled mask/occulter has been designed for the visible spectrum range. The mask/occulter can suppress the intensity along the optical axis up to ten orders of magnitude. The design process can tailor the mask shape, number of petals, and transparency level to the near-field and far-field diffraction region. The mask/occulter can be used in space astronomy, ground-based telescope, and high-energy laser systems, and optical lithography to eliminate the Poisson Spot.

This work was done by Ron Shahram Shiri of Goddard Space Flight Center, and Wasyl Wasylkiwskyj of The George Washington University. Further information is contained in a TSP (see page 1). GSC-16588-1