Laser-Induced-Fluorescence Photogrammetry and Videogrammetry

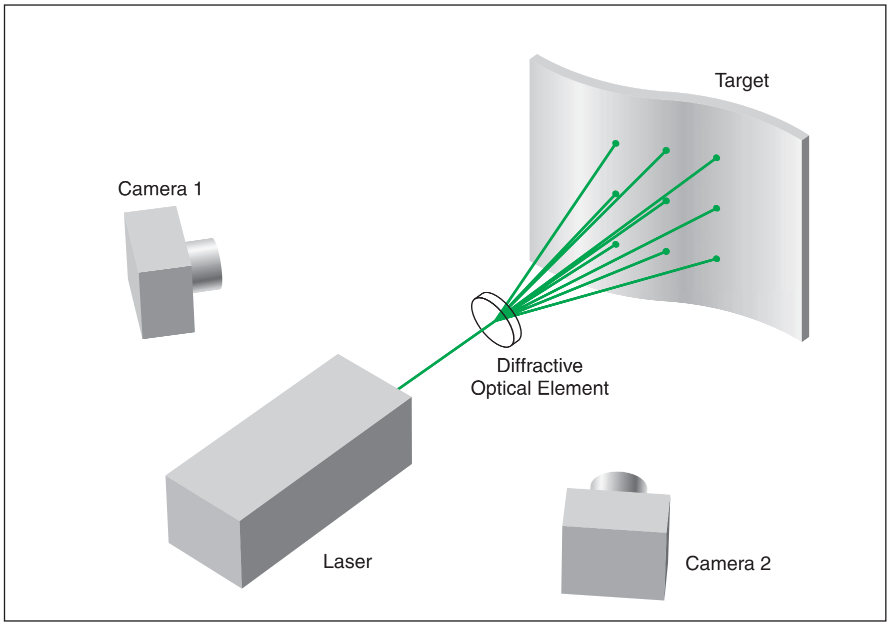
Signal-to-noise ratios are enhanced and effects of laser speckle suppressed.

Langley Research Center, Hampton, Virginia

An improved method of dot-projection photogrammetry and an extension of the method to encompass dot-projection videogrammetry overcome some deficiencies of dot-projection photogrammetry as previously practiced. The improved method makes it possible to perform dot-projection photogrammetry or videogrammetry on targets that have previously not been amenable to dot-projection photogrammetry because they do not scatter enough light. Such targets include ones that are transparent, specularly reflective, or dark.

In standard dot-projection photogrammetry, multiple beams of white light are projected onto the surface of an object of interest (denoted the target) to form a known pattern of bright dots. The illuminated surface is imaged in one or more cameras oriented at a nonzero angle or angles with respect to a central axis of the illuminating beams. The locations of the dots in the image(s) contain stereoscopic information on the locations of the dots, and, hence, on the location, shape, and orientation of the illuminated surface of the target. The images are digitized and processed to extract this information. Hardware and software to implement standard dot-projection photogrammetry are commercially available.

Success in dot-projection photogrammetry depends on achieving sufficient signal-to-noise ratios: that is, it depends on scattering of enough light by the target so that the dots as imaged in the camera(s) stand out clearly against the ambient-illumination component of the image of the target. In one technique used previously to increase the signal-to-noise ratio, the target is illuminated by intense, pulsed laser light and the light entering the camera(s) is band-pass filtered at the laser wavelength. Unfortunately, speckle caused by the coherence of the laser light engenders apparent movement in the projected dots, thereby giving rise to errors in the measurement of the centroids of the dots and corresponding errors in the computed shape and location of the surface of the target.



A **Laser Beam Is Split** into multiple beams to form dots of illumination on a target. The dots are observed by use of stereoscopic cameras.

The improved method is denoted laser-induced-fluorescence photogrammetry. In preparation for observation by this method, a target is made fluorescent by whichever of several techniques is most appropriate. Examples include the following:

- A target sheet or membrane (e.g., a membrane subject to deflections that one seeks to measure) made of a transparent or translucent polymer could be doped with a fluorescent dye during its manufacture. If, in addition, the target were coated on one side with metal to render it specularly reflective, then it could be positioned for photogrammetric observation of its uncoated side.
- A thick transparent, translucent, or dark opaque object (e.g., a wind-tunnel model, the position, orientation, and deflection of which one seeks to measure) could be doped with a fluorescent dye during its manufacture.
- A specularly reflective or dark object that has already been manufactured could be coated with a paint or lacquer containing a dissolved fluorescent dye.
- The surface of a part of a human body to be observed photogrammetrically could be coated painted or sprayed with a harmless fluorescent dye in a nontoxic solvent.
- A fluorescent dye could be dissolved in a body of liquid, which could be, for example, water in a tank for experiments on the sizes, shapes, and motions of waves.

In this method, a laser beam is pulsed and is split into multiple beams by use of a commercially available diffractive optical element (see figure). The laser beams form dots of light on the target, exciting fluorescence in the dye. Unlike the laser light, the fluorescence from the dots is incoherent and therefore, there is no laser speckle in the fluorescence. Like scattered light, the fluorescent light is emitted in all directions.

The cameras are time-gated to acquire images only during the interval of maximum fluorescence following the laser pulse, to suppress the contribution of ambient light between pulses. To suppress ambient light further, the light entering the cameras is band-pass filtered at the fluorescence wavelength, which is longer than the laser wavelength. This filtering also blocks directly reflected laser light, which, if allowed to enter the cameras, could give rise to spurious dot images.

The extension of the method to videogrammetry is straightforward: The laser and cameras can be operated in a sequence of pulses to acquire a sequence of projected-dot images. The images, or the sets of location and shape data extracted from the images, can be used to synthesize a motion picture showing how the target surface moves and/or deflects over time.

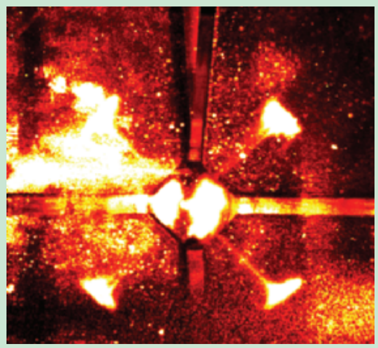
This work was done by Paul Danehy, Tom Jones, John Connell, Keith Belvin, and Kent Watson of **Langley Research Center**. *Further information is contained in a TSP (see page 1).* *LAR-16426*

Laboratory Apparatus Generates Dual-Species Cold Atomic Beam

A pyramidal magneto-optical trap extracts atoms from one chamber into another.

NASA's Jet Propulsion Laboratory, Pasadena, California

A laser cooling apparatus that generates a cold beam of rubidium and cesium atoms at low pressure has been constructed as one of several intermediate products of a continuing program of research on laser cooling and atomic physics. Laser-cooled atomic beams, which can have temperatures as low as a microkelvin, have been used in diverse applications that include measurements of fundamental constants, atomic clocks that realize the international standard unit of time, atom-wave interferometers, and experiments on Bose-Einstein condensation. The present apparatus is a prototype of one being evaluated for use in a proposed microgravitational experiment called the Quantum Interferometric Test of Equivalence (QuITE). In this experiment, interferometric measurements of cesium and rubidium atoms in free fall would be part of a test of Einstein's equivalence principle. The present apparatus and its anticipated successors may also be useful in other experiments, in both microgravity and normal Earth gravity, in which there are requirements for dual-species atomic beams, low temperatures, and low pressures.



This is a **False-Color Image** of fluorescence from cesium atoms in the pyramidal magneto-optical trap. The cold atomic beam in the extraction column is visible in the side views afforded by the 45° mirrors.

The apparatus includes a pyramidal magneto-optical trap in which the illumination is provided by multiple lasers tuned to frequencies characteristic of the two atomic species. The inlet to the apparatus is located in a vacuum chamber that contains rubidium and cesium atoms at a low pressure; the beam leaving through the outlet of the apparatus is used to transfer the atoms to a higher-vacuum (lower-pressure) chamber in which measurements are performed.

The pyramidal magneto-optical trap is designed so that the laser cooling forces in one direction are unbalanced, resulting in a continuous cold beam of atoms that leak out of the trap (see figure). The radiant intensity (number of atoms per unit time per unit solid angle) of the apparatus is the greatest of any other source of the same type reported to date. In addition, this is the first such apparatus capable of producing a slow, collimated beam that contains two atomic species at the same time.

This work was done by Robert Thompson, William Klipstein, James Kohel, Lute Maleki, Nathan Lundblad, Jaime Ramirez-Serrano, Dave Aveline , Nan Yu, and Daphna Enzer of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP (see page 1).* *NPO-30396*

Laser Ablation of Materials for Propulsion of Spacecraft

Marshall Space Flight Center, Alabama

A report describes experiments performed as part of a continuing investigation of the feasibility of laser ablation of materials as a means of propulsion for small spacecraft. In each experiment, a specimen of ablative material was mounted on a torsion pendulum and irradiated with a laser pulse having an energy of 5 J. The amplitude of the resulting rotation of the torsion pendulum was taken to be an indication of the momentum transferred from the laser beam. Of the ablative materials tested, aluminum foils yielded the smallest rotation amplitudes — of the order of 10°. Black coating materials yielded rotation amplitudes of the order of 90°. Samples of silver coated with a fluorinated ethylene propylene (FEP) copolymer yielded the largest rotation amplitudes — 6 to 8 full revolutions. The report presents a theory involving heating of a confined plasma followed by escape of the plasma to explain the superior momentum-transfer performance of the FEP specimens. It briefly discusses some concepts for optimizing designs of spacecraft engines to maximize the thrust obtainable by exploiting the physical mechanisms of the theory. Also discussed is the use of laser-ablation engines with other types of spacecraft engines.

This work was done by David L. Edwards, Ralph Carruth, and Jonathan Campbell of **Marshall Space Flight Center** *and Perry Gray of Native American Services.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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