



## Optical Measurement of Mass Flow of a Two-Phase Fluid

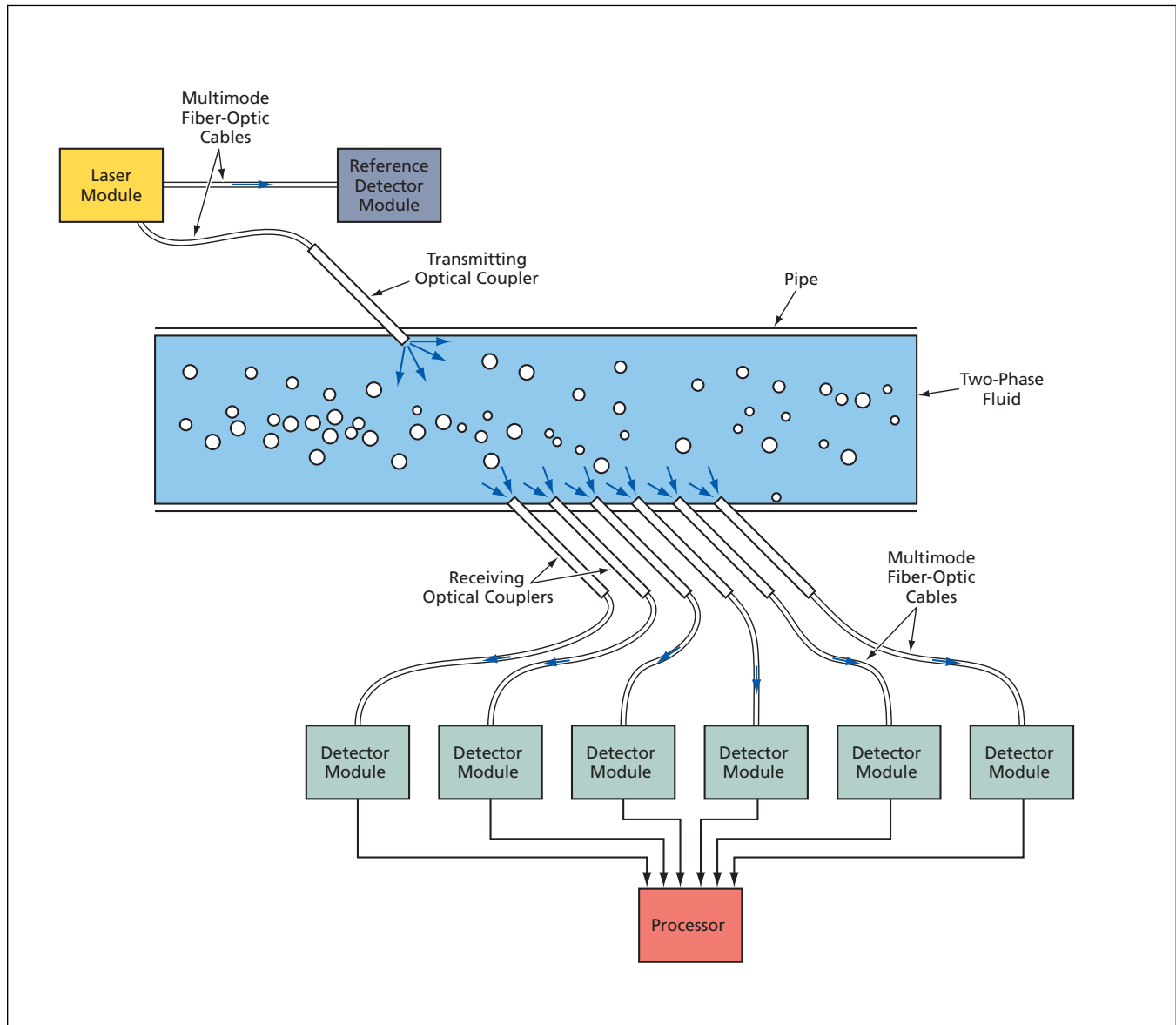
Density and mass flow are estimated from wavelength-dependent scattering of light.

Marshall Space Flight Center, Alabama

An optoelectronic system utilizes wavelength-dependent scattering of light for measuring the density and mass flow of a two-phase fluid in a pipe. The apparatus was invented for original use in measuring the mass flow of a two-phase cryogenic fluid (e.g., liquid hydrogen containing bubbles of hydrogen gas), but underlying principles of operation can readily be adapted to non-cryogenic two-phase fluids.

The system (see figure) includes a laser module, which contains two or more laser diodes, each operating at a different wavelength. The laser module also contains beam splitters that combine the beams at the various wavelengths so as to produce two output

beams, each containing all of the wavelengths. One of the multiwavelength output beams is sent, via a multimode fiber-optic cable, to a transmitting optical coupler. The other multiwavelength output beam is sent, via another multimode fiber-optic cable, to a reference detector module, wherein fiber-optic splitters split the light into several multiwavelength



Laser Light at Multiple Wavelengths is introduced into a two-phase fluid in a pipe at one point. After scattering by the fluid, the light is detected at multiple points on the opposite side of the pipe.

beams, each going to a photodiode having a spectral response that is known and that differs from the spectral responses of the other photodiodes. The outputs of these photodiodes are digitized and fed to a processor, which executes an algorithm that utilizes the known spectral responses to convert the photodiode outputs to obtain reference laser-power levels for the various wavelengths.

The transmitting optical coupler is mounted in (and sealed to) a hole in the pipe and is oriented at a slant with respect to the axis of the pipe. The transmitting optical coupler contains a collimating lens and a cylindrical lens that form the light emerging from the end of the fiber-optic cable into a fan-shaped

beam in a meridional plane of the pipe. Receiving optical couplers similar to the transmitting optical couplers are mounted in the same meridional plane at various longitudinal positions on the opposite side of the pipe, approximately facing the transmitting optical coupler along the same slant.

Light collected by each receiving optical coupler is sent, via a multimode fiber-optic cable, to a detector module similar to the reference detector module. The outputs of the photodiodes in each detector module are digitized and processed, similarly to those of the reference detector module, to obtain indications of the amounts of light of each wavelength scattered to the correspon-

ding receiving position. The value for each wavelength at each position is also normalized to the reference laser-power level for that wavelength. From these normalized values, the density and the mass flow rate of the fluid are estimated.

*This work was done by John Wiley and Kevin Pedersen of Marshall Space Flight Center; Valentin Korman of Madison Research Corp., and Don Gregory of the University of Alabama at Huntsville.*

*This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32031-1.*

## Selectable-Tip Corrosion-Testing Electrochemical Cell

**The diameter and average depth of a corrosion pit can be selected.**

*John F. Kennedy Space Center, Florida*

The figure depicts aspects of an electrochemical cell for pitting-corrosion tests of material specimens. The cell is designed to generate a region of corrosion having a pit diameter determined by the diameter of a selectable tip. The average depth of corrosion is controlled by controlling the total electric charge passing through the cell in a test. The cell is also designed to produce minimal artifacts associated with crevice corrosion.

There are three selectable tips, having diameters of 0.1 in. (0.254 cm), 0.3 in. (0.762 cm), and 0.6 in. (1.524 cm), respec-



This Corrosion-Testing Electrochemical Cell is equipped with one of three selectable tips. Each tip features a different corrosion-pit diameter.

tively. The amount of electric charge needed to generate a corrosion pit having desired average depth  $h$  at a selected diameter  $d$  is given straightforwardly by

$$Q = F\rho\pi d^2 h / (4W)$$

$F$  is the Faraday constant (the charge of one mole of electrons),  $\rho$  is the mass density of the specimen material, and  $W$  is the equivalent weight of the material (the mass of one mole of the material divided by the valence of the material).

*This work was done by Janice Lomness and Paul Hintze of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13045*

## Piezoelectric Bolt Breakers and Bolt Fatigue Testers

**Safer alternative to spacecraft explosive bolts may accelerate fatigue testing on Earth.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed family of devices for inducing fatigue in bolts in order to break the bolts would incorporate piezoelectric actuators into resonant fixtures as in ultrasonic/sonic drills/corers and similar devices described in numerous prior *NASA Tech Briefs* articles. These devices were originally intended primarily for use as safer, more-reliable, more-versatile alter-

natives to explosive bolts heretofore used to fasten spacecraft structures that must subsequently be separated from each other quickly on command during flight. On Earth, these devices could be used for accelerated fatigue testing of bolts.

Fatigue theory suggests that a bolt subjected to both a constant-amplitude dynamic (that is, oscillatory) stress and a

static tensile stress below the ultimate strength of the bolt material will fail faster than will a bolt subjected to only the dynamic stress. This suggestion would be applied in a device of the proposed type. The device would be designed so that the device and the bolt to be fatigue-tested or broken would be integral parts of an assembly (see figure).