September 1972

B72-10310

NASA TECH BRIEF

Ames Research Center

Optical Enhancement of Sensitivity in Laser Doppler Velocity Systems

The problem:

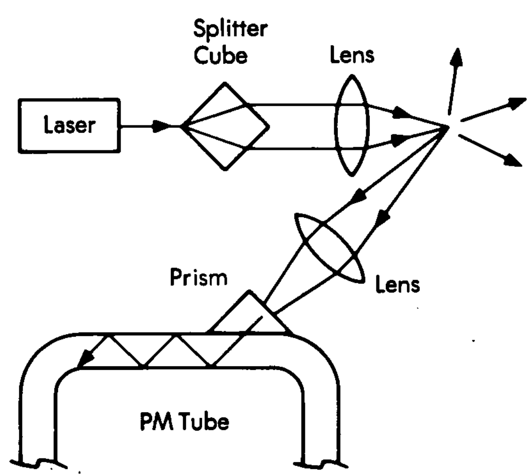
Laser Doppler velocity (LDV) systems are used to determine flow velocities in gas streams; the systems permit measurement of the Doppler shift which occurs when radiation is scattered by moving particles. Performance of LDV systems is often marginal because signals are weak when the amount of dust or other particulate matter in the gas stream is very small. Particles can be added to the stream, but often this is not practical. Alternatively, the signal at the detector can be increased by using a more powerful laser, but this is undesirable in terms of cost, and some systems already use the largest lasers. Thus, it was necessary to develop methods which would increase the sensitivity of detection of signals.

The solution:

Use optical enhancement techniques to prevent loss of light by reflections at the photocathode of a photomultiplier.

How it's done:

A prism is used to introduce light into the end window of the photomultiplier tube at a sufficiently oblique angle so that it is trapped in the window by total reflection; thus, every time light reaches either the air-glass or the vacuum-photocathode interface, it is reflected back into the window. After a few reflections, nearly all incident light will have been absorbed by the photocathode; thus, light which would have been lost is conserved by the optical enhancement technique. As a result, sensitivity is increased by about a factor of two for blue light and about a factor of five for red light. However, since optical heterodyne systems require precise alignment in order to function, it might appear that the technique of optical enhancement of photomultipliers can not be applied



to LDV systems; in fact, the optical enhancement method described above can not be used with some detection geometries.

The class of LDV systems that is often called self-aligned, self-focused, or two-beam, projects two beams instead of one into the gas to be measured. In these systems, a single parallel beam from a laser is split into two parallel beams separated by a small distance; the beams strike a lens and are brought to a common focus at a point in the focal plane of the lens. All of the interference occurs at the common point of focus, and light going out in *any* direction from that point consists of rays scattered from both beams, coincident

(continued overleaf)

and colinear. The light perceived at an observation point simply turns on and off at a heterodyne frequency of the order of a few kilohertz or megahertz. Moreover, because the heterodyne frequency is the difference between the Doppler shifts of the two scattered beams, it is the same frequency for light scattered in any direction. The diagram indicates how optical enhancement can be used with a self-focusing LDV system. The many arrows leaving the focal point imply that light scattered in any direction can be collected and used to generate a signal.

In experiments with argon and helium-neon lasers, optical enhancement provided sensitivities two to four times greater than could be obtained in the same LDV systems without optical enhancement of the photomultiplier sensitivity.

References:

1. Gunter, W. D., Jr.; Grant, G. R.; and Shaw, S. A.: Optical Devices to Increase Photocathode Quantum Efficiency. Applied Optics, vol. 9, p. 251, 1970.
2. Gunter, W. D., Jr., and Grant, G. R.: Optical Enhancement of Photomultiplier Sensitivity, NASA Tech Brief 71-10113.

Note:

No additional documentation is available. Specific questions, however, may be directed to:

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Reference: B72-10310

Patent status:

No patent action is contemplated by NASA.

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