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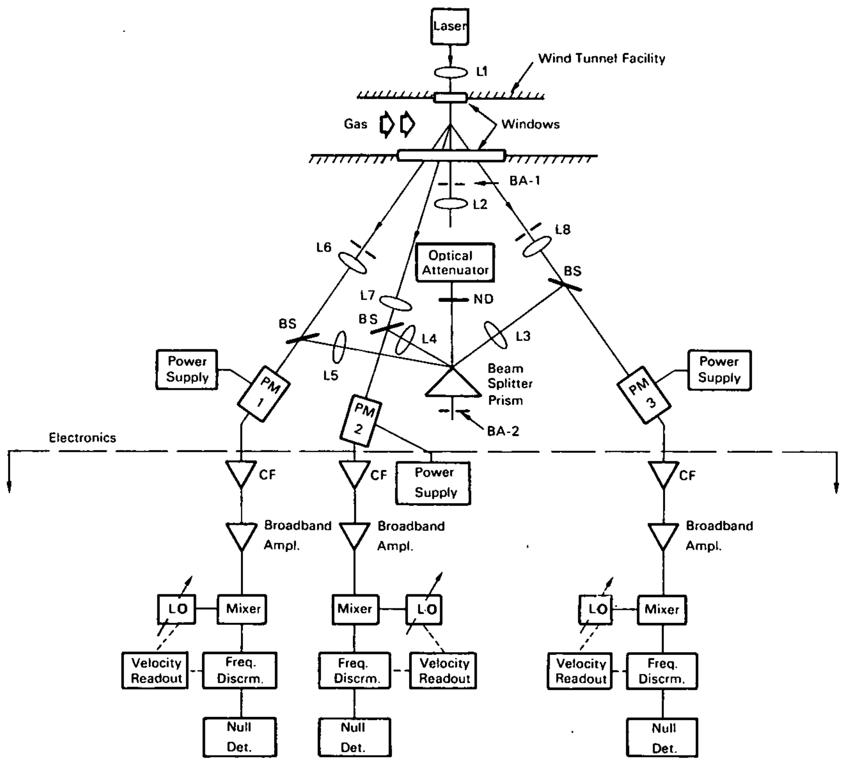
NASA TECH BRIEF

Laser Doppler Gas-Velocity Instrument



A 3-D instrument using a laser light source has been designed to measure both turbulence and mean velocity of subsonic and supersonic gas flows. This instrument is based on the measurement of the Doppler frequency shift of light waves scattered by moving particles in the gas stream. Using an experimental laboratory model of the system, gas velocities of up to Mach 2 were measured in the NASA seven-inch wind tunnel facilities. With smoke injected into the gas flow to provide scattering particles, signal-to-noise ratios of 20 to 30 dB were obtained using a 1-watt argon laser.

The schematic diagram outlines the essential features of the instrument. The light from the laser passes through lens L1 and a window in the wind tunnel or test facility to focus at a selected point in the flow stream. The unscattered beam is collected after passing through a boresight alignment aperture (BA-1) and rendered parallel by lens L2. The parallel beam passes through an optical attenuator and neutral density filter (ND) for adjustment of beam intensity, in accordance with specified operating criteria. The optical local oscillator beam is obtained for the three photomultiplier (PM) mixers by dividing the beam

(continued overleaf)

with a tetrahedral beam splitting prism, finally reflecting in each scattered beam. Lenses L3, L4, and L5 focus the local oscillator signals onto the photomultiplier cathodes. The top corner of the tetrahedral prism is ground off to allow a small portion of the beam to pass straight through the prism, out of the base, and through a second boresight aperture (BA-2). By using the two boresight apertures, a reference baseline is established for alignment of the whole instrument.

Each scattered beam is picked up at a fixed angle to the laser beam, the angles being symmetrically situated around the axis of the reference beam. Lenses L6, L7, and L8, behind adjustable apertures, collect the scattered light at the chosen angle. After passing through suitable optical collimating and focusing components, the scattered beams pass through the beam-splitter mirrors (BS), and onto the photomultiplier cathode where the scattered signal is mixed with the local oscillator (unscattered reference) beam. The scattered beam lens system is somewhat more complicated than shown schematically, to provide independent control of the scattering volume and instrument broadening at one end and of the mixing process at the opposite end of the optical systems.

Refractor plates are situated at several places in the optical paths to permit independent parallel alignment with respect to transverse locations of the beam at the photomultiplier cathodes. Angular beam adjustment at the photocathodes is provided by the beam-splitters.

At each photomultiplier active surface, the scattered light heterodynes with the unscattered reference beam (local oscillator beam). The heterodyne outputs of the photomultipliers pass through impedance matching preamplifiers (CF). The signals are then amplified and further processed in the electronics section of the system. Spectrum analyzers are used as monitors, while the turbulence and velocity information is obtained by processing through special discriminator circuits. To optimize the signal-to-noise ratio, frequency tracking discriminators are used which continuously track the frequency of the fluctuating turbulence Doppler signals. The three orthogonal components of the gas velocity vector are calculated from measurements of the Doppler shift at the three scattering angles.

Further work remains to be done on several problems: (1) the construction of a special signal frequency tracker, which should result in an improved signal-to-noise ratio and wider operating range; (2) the establishment of a more acceptable injectant material for the light scattering process; (3) the acquisition of turbulence data in a number of different systems, using the 3-D vector velocity instrument; (4) the investigation of methods of reducing or eliminating instrumental frequency broadening; and (5) the further development of the device for cross-correlation measurements. Experiments have shown that with an increased instrument sensitivity, scattering from natural air contaminants, such as dust and water drops may prove feasible, eliminating the use of artificial injectants.

Notes:

1. A similar instrument for a single scattering angle is described in Tech Brief 66-10693.
2. Complete details may be obtained from:
   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama 35812
   Reference: B68-10349

Patent status:

No patent action is contemplated by NASA.

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