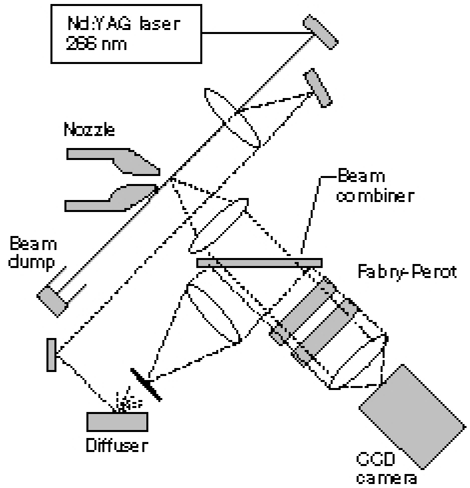
Ultraviolet Molecular Rayleigh Scattering Used to Measure Velocity in High-Speed Flow

Molecular Rayleigh scattering offers a means to measure gas flow parameters including density, temperature, and velocity. No seeding of the flow is necessary. The Rayleigh scattered power is proportional to the gas density, the spectral width is related to the gas temperature, and the shift in the frequency of the spectral peak is proportional to one component of the fluid velocity. Velocity measurements based on Rayleigh scattering are more suitable for high-speed flow, where the bulk fluid velocity is on the order of, or larger than, the molecular thermal velocities. Use of ultraviolet wavelengths for Rayleigh scattering diagnostics is attractive for two reasons. First, the Rayleigh scattering cross section is proportional to the inverse 4th power of the wavelength. And second, the reflectivity of metallic surfaces is generally less than it is at longer wavelengths. This is of particular interest in confined flow situations, such as in small wind tunnels and aircraft engine components, where the stray laser light scattered from the windows and internal surfaces in the test facility limits the application of Rayleigh scattering diagnostics.

In this work at the NASA Lewis Research Center, molecular Rayleigh scattering of the 266-nm fourth harmonic of a pulsed, injectionseeded Nd:YAG (neodymium:yttrium-aluminum-garnet) laser was used to measure velocity in a supersonic free air jet with a 9.3-mm exit diameter. The frequency of the Rayleigh scattered light was analyzed with a planar mirror Fabry-Perot interferometer used in a static imaging mode, with the images recorded on a cooled, high-quantum-efficiency charge-coupled discharge (CCD) camera. In addition, some unshifted light from the same laser pulse was imaged through the interferometer to generate a reference. Data were obtained with single laser pulses at velocities up to Mach 1.3. The measured velocities were in good agreement with velocities calculated from isentropic flow relations.

Our conclusion from this study was that ultraviolet Rayleigh scattering is preferable in confined flow situations because of the increase in the ratio of Rayleigh scattering signal to stray laser light. On the other hand, in open flows, such as free jets and larger wind tunnels where stray laser light can be controlled, visible Rayleigh scattering is preferable.



Setup for Rayleigh scattering measurements in free jet.

Bibliography

Seasholtz, R.G.: Single-Shot Spectrally Resolved UV Rayleigh Scattering Measurements in High Speed Flow. NASA TM-107323, 1996.

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