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RAYLEIGH SCATTERING OF 6943Å LASER RADIATION IN A NITROGEN ATMOSPHERE

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Rayleigh's theory of incoherent light scattering in a molecular atmosphere is based on negligible interaction between molecules. Each molecular dipole scatters independently with the result that the total intensity is the sum of the intensity per scatterer times the number of scatterers. The theory also predicts a constant angular distribution of scattered radiation for perpendicularly polarized incident radiation and a $\cos^2\theta$ distribution for parallel-polarized incident radiation. In the study of scattering produced by the intense coherent radiation of ruby lasers, it is of basic importance to determine if the incoherent theory applies or to what extent there may be a coherent contribution.

The angular distribution of scattered radiation in both an argon and a xenon atmosphere has been recently investigated by George et al.[1,2] Their experiment was conducted with the ruby laser operating in a non-Q-switched manner, which resulted in a large number of random pulses, each of approximately 1-μsec time duration and of random amplitude distribution. Measurements of the scattered radiation were made with the E vector of the incident beam both perpendicular and parallel to the plane of observation. George's results indicate a departure from the incoherent scattering theory. This motivated further investigation since it appears that coherence can produce deviations from the independent scattering theory under certain experimental conditions.[3]

The present experiment was designed to investigate the angular distribution of scattered radiation in a nitrogen atmosphere using an unfocused single giant pulse of short time duration. Nitrogen was chosen for the convenience of simulating a dust-free earth atmosphere. The ruby laser, operating with both an active and a passive Q-switching element in tandem, produced a single giant pulse of 20-nsec duration. The basic experimental arrangement is shown in Fig. 1.

Energy in the unfocused beam was measured to be 0.2 J (10-MW peak power) in the observation chamber. The peak intensity of each angular measurement was referenced to the peak intensity of the incident beam measured from the scattering at the exit window. The size and position of the aperture gave the beam a well-defined geometry. The inside wall of the aluminum tubing was threaded and anodized flat black, thus aiding the baffles in reducing spurious light to a negligible level. During the initial alignment, the top of the cylindrical observation chamber was replaced with a Plexiglas panel. This facilitated the visual detection of dust particles and provided a check on the alignment. The nitrogen gas used in the experiment was replenished after each measurement to avoid contamination by laser-produced particles. The observation holes were positioned to an accuracy of 0.1°. The fiber-

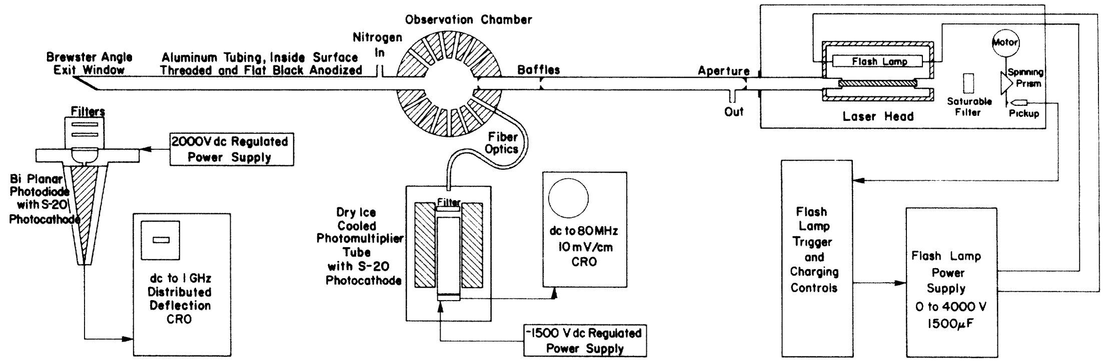

FIG. 1. Diagram of experimental arrangement for the measurement of Rayleigh scattering.

optics input used these holes as an index. Optically flat windows in the observation ports had less than 2% deviation in transmission. The fiber-optics output illuminated the entire S-20 photocathode, reducing any sensitivity changes due to photocathode nonuniformity. The use of fiber optics also reduced the possibility of magnetic field changes, geomagnetic and local, from influencing the gain of the 11-stage dynode amplifier.

Measurements of the intensity of the scattered light are given in Fig. 2 for both polarizations of the incident beam. The circles represent the mean of five individual measurements and are superimposed on the theoretical curves. Also shown are the 95% confidence limits. Both curves were normalized arbitrarily to 90°. As can be seen, there is no noticeable change in the scattering pattern predicted by theory for either polarization of the incident beam. In addition, the depolarization factor for nitrogen, as previously determined both theoretically and experimentally, ranges from 0.021 to 0.036.[4,5] The results of our experiment indicate a value of 0.032, in reasonable agreement with the value expected. The fact that coherence does not cause departure from Rayleigh scattering is in agreement with measurements made in low-turbidity molecular liquids when the highly coherent radiation from a helium-neon gas laser was used as a source.[6]

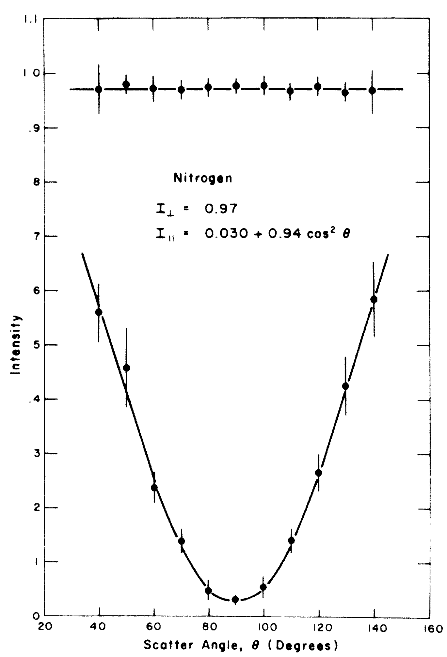

FIG. 2. Angular distribution of scattered radiation in nitrogen at atmospheric pressure and temperature for perpendicular- and parallel-polarized incident light.

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