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MULTIPLE SCATTERING OF LASER BEAMS IN DENSE HYDROSOLS

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The multiple scattering of laser beams is usually described within the framework of small-angle scattering theory. The purpose of this investigation is to study the validity of this approximation as well as improvements due to the incorporation of diffusion theory in the calculations.

We measured the intensity (power per unit area within the detector's field of view) of scattered laser light from an optically dense hydrosol and compared the measured intensities to those calculated from a multiple scattering theory. The nonabsorbing hydrosol was composed of 2.26 ± 0.07 μm diameter polystyrene spheres suspended in essentially scatter-free water. We injected a HeNe laser beam perpendicular to and at the center of one face of a 10x10x10 cm tank containing this suspension. The intensity of the scattered light at the exit face of the tank was measured to a relative accuracy of 1% with a photomultiplier tube (Fig. 1). The axis of the photomultiplier was parallel to the incident beam and the half-angle field of view (FOV) was either 0.357 deg or approximately 90 deg. In both cases the diameter of the detector aperture was 500 μm. We measured the intensity at the exit face of the tank in 100 μm steps from the center of the emerging laser beam to a radial distance of 4 cm. We also recorded the shapes of the intensity distributions from both the exit face and side of the tank with a densitometric television camera (Fig. 2) and displayed them on a false-color image analyzer. An intensity distribution from the side of the tank is shown in Fig. 3, in which the laser beam enters from the left. Each color band, shown here in black and white, represents an equal range in the logarithm of the intensity.

An example of the comparison of the calculated and measured irradiances from the exit face of the tank is shown in Fig. 4 for the 90 deg half angle FOV detector and an optical depth of 5.02, as a function of radial distance from the beam center. In the figure both the measured irradiance and the calculated total scattering are normalized to unity at the beam center. The contributions to the total scattering from the attenuated laser beam, small-angle approximation and diffusion theory are separately displayed. They are labelled, respectively, unscattered, scattered and diffuse. The experimental data are shown by the open symbols which are considerably larger than the 1% errors in the measurement.

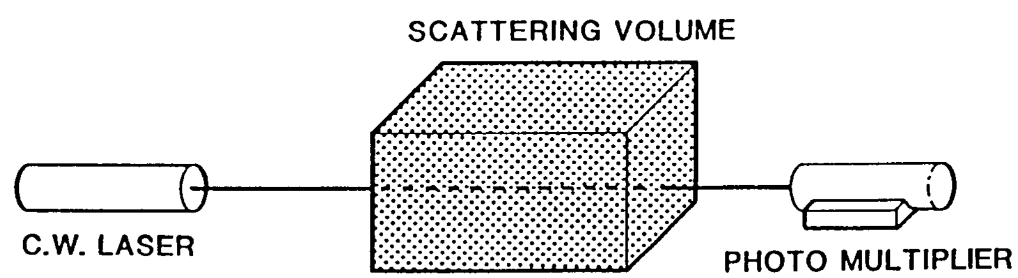

Fig. 1. Scattering geometry with the scanning photomultiplier tube detector.

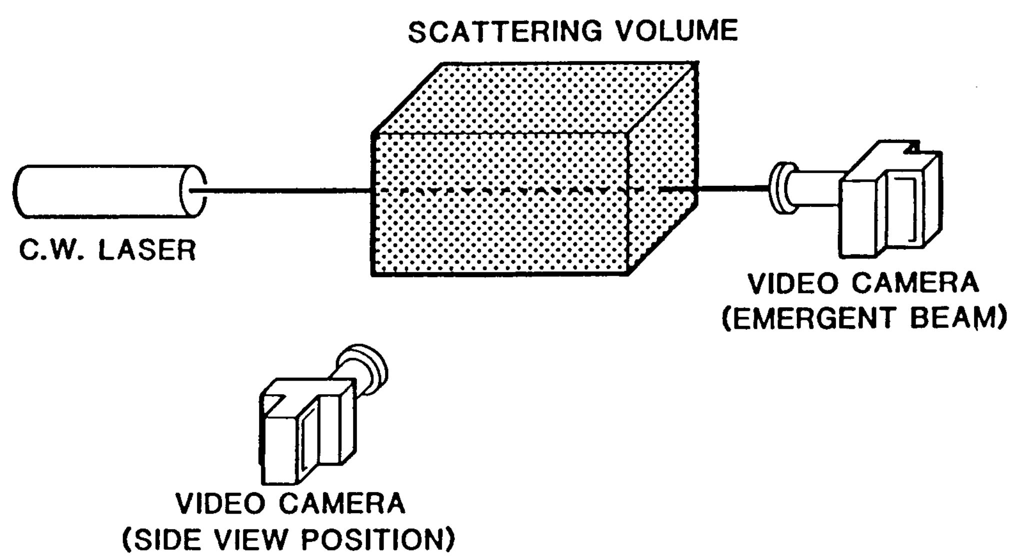

Fig. 2. Scattering geometry with the densitometric television system.

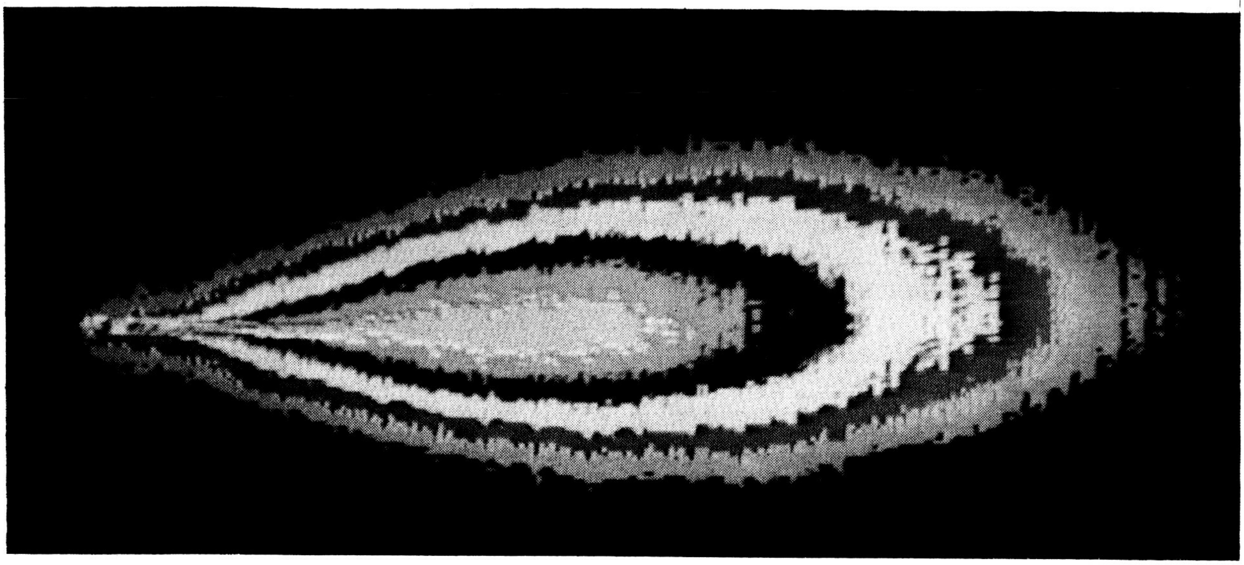

Fig. 3. Intensity contours measured from the side of the scattering tank. Equal ranges in the logarithm of the scattering intensity are plotted. The laser beam enters from the left in the figure.

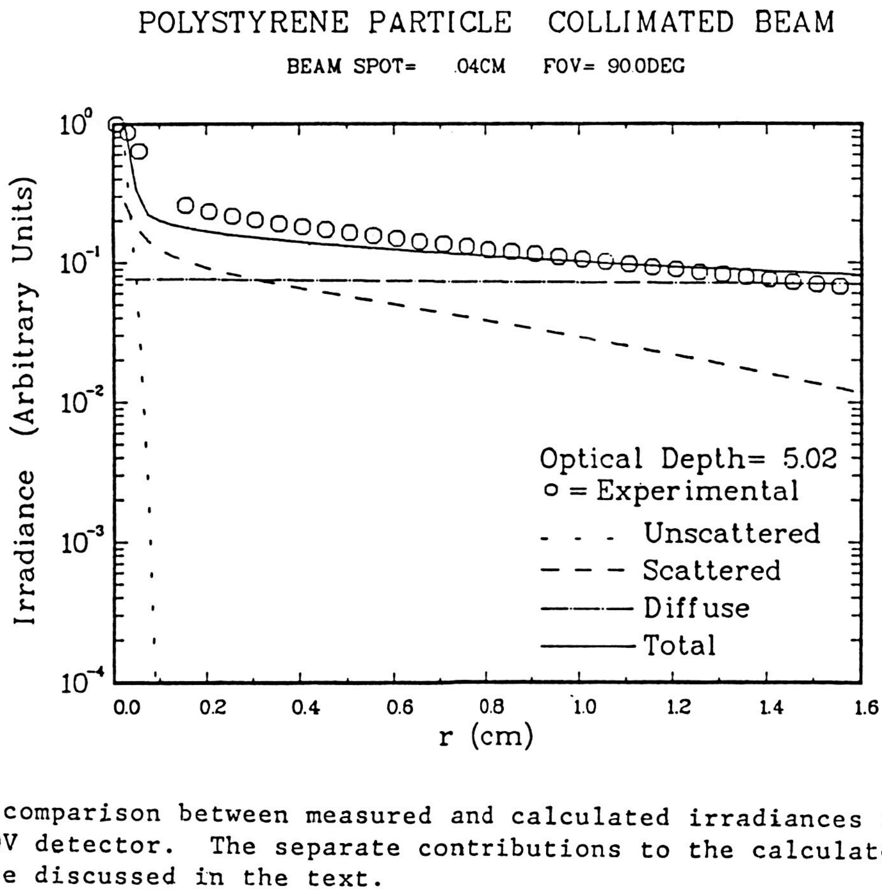

Fig. 4. A comparison between measured and calculated irradiances for the open FOV detector. The separate contributions to the calculated results are discussed in the text.