Polarized Light Scattering by Small Particles

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All of the polarized light scattering properties of single particles and suspensions of particles are contained in the 16-element Mueller matrix. For single-particle studies the particle is electrostatically suspended, the light scattering functions are measured, and the particle is then extracted from the suspension chamber by placing it on the point of a needle. The particle is examined subsequently with an electron microscope to determine precisely its size and shape. Results will be presented for single polystyrene spheres, sphere multiplets, approximately cubic NaCl crystals, and cubes of MgO. Recent studies of suspensions have concentrated on oceanic hydrosols. Some results and general features of these hydrosols will be presented.

INTRODUCTION

The single most important entity in radiative transfer theory is the Mueller matrix. If one wants to determine the transfer of radiation, for both single and multiple scattering, through fogs, smokes, etc., this 4×4 matrix is essential for a complete understanding of the scattered radiation field. The matrix measured at all scattering angles contains, in effect, the result of every elastic light scattering experiment that could be performed.

Measurement of the matrix requires, in principle, determining the linear and circular polarization intensities of the scattered light for all possible independent linear and circular polarization states of the incident light. We have developed an instrument that multiplexes this information in such a way that each matrix element appears as the amplitude of a different frequency component in the photomultiplier signal produced by the scattered light. The instrument has been previously described in detail by Thompson (1978) and Thompson et al. (1980).

The first matrix element f_{11} is the scattering function; it is the quantity generally measured in light scattering studies and corresponds to the situation in which the incident light is unpolarized and the scattered light is detected without regard to polarization. To make absolute measurements of it, which we have not done, one must determine calibration factors such as detector sensitivity, absolute radiances, and in the case of particulate suspensions, the size of the observed scattering volume. Our instrument automatically normalizes the other 15 elements to f_{11}, and thus these calibration factors, as well as the errors associated with their determination, are eliminated. Consequently, the 15 matrix elements will be presented on a scale on which they are restricted to values between $+1$ and -1.

Two general comments about the form of the matrices are in order. First, Van de Hulst (1957) has pointed out that for a single particle in fixed orientation there are only seven independent matrix elements. Thus there are nine independent equalities relating the 16 matrix elements; these are given by Fry and Kattawar (1981). Second, Van de Hulst (1957) has shown that if the particle has a plane of symmetry and the matrix is averaged over particle orientations, as

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