MULTIPLE SCATTERING MEASUREMENTS IN LABORATORY AND FOGGY ATMOSPHERE

P.Bruscaglioni, E.Battistelli, P.Pili, G.Zaccanti

Department of Physics - Via S.Marta,3 Firenze Italy

Multiple scattering affects propagation of light beams in turbid media. Backscattering or forward scattering based measurements of atmospheric parameters are influenced by this effect. Although largely studied theoretically, the effect needs measurements in controlled situations due to the large variety of situations of practical importance.

The aim of this paper is to present the results of laboratory measurements pertaining to the trasmission of a collimated light beam (HeNe source, 10 mW) through suspensions of latex spheres in water and to make a comparison with the predictions of calculations. Some results pertaining to light beam propagation in a foggy atmosphere will also be presented.

In the laboratory the transmitted power was measured by an optical receiving system whose Field of View was varied in 6 steps between $\alpha = 0.5$ and $\alpha = 3$ (semiaperture). The optical depth of the suspensions was also varied during the measurements.

The dependence of the received power, P_R, on the F.O.V. semiaperture α and on the optical depth τ was analyzed. By analyzing P_R as a function of α, with τ fixed, we were able to separate the contribution P_0 pertaining to the attenuated beam (1), since the trasmitted power of the collimated beam did not vary with α.

The presence of inhomogeneities of the medium interposed between a source and a receiver can cause the amount of received scattered power to vary with respect to the case of a homogeneous medium with the same optical depth. Results of numerical computations indicated that, given the optical depth, when the extinction coefficient is larger in the proximity of the receiver the relative contribution of forward scattering to the received power increases. (2)

To make a simple verification of this effects, during laboratory measurements, for each value of the optical depth of the suspension, measurements were repeated with different values of the distance D between the vessel containing the suspension and the receiver.

Fig.1 gives an example of a comparison between measured and calculated ratio P_s/P_o (scattered power divided by attenuated beam power) plotted versus τ . The figure refers to polystyrene spheres with average radius 7.85 μm. The crosses connected by the continuous lines in Fig. 1a, b indicate the measured ratios. The squares indicate the ratios calculated by taking into account ten orders of scattering (3).

A comparison between the data of Fig. 1a, b shows the increase of received scattered power occurring when the suspension is nearer the receiver.

The effect was confirmed for other cases relative to different types of spheres and other values of α .

To have a detailed comparison with the results of calculations an analysis was made aiming at examining the contributions of first and second orders of scattering separately. This was possible since, under assumption of validity of the small angle approximation, the ratio P_s/P_o can be represented (for a given geometry) by a polynomial in τ (see for instance ref. (4) eq. 10, or also ref. (1)). Thus one can write for α and D fixed:

$$P\ /P\ = K_1(\alpha)\tau + K_2(\alpha)\tau^2 + \ldots\ldots$$

where the term $K_m(\alpha)$ corresponds to the contribution of mth order of scattering.

From the dependence on α of K_1 , one can deduce the scattering function $L(\vartheta)$ of the suspension.

Fig.2 shows an example of $K_1(\alpha)$ in the interval 0 – 3° obtained for polystyrene spheres with average radius 7.85μm. The obtained scattering function was fitted to a Gaussian function: $A \exp(-a\alpha^2)$.

The deduced parameters A and a are indicated in the figure and compared with those obtained from Mie theory.

Transmission measurements in a foggy atmosphere were also carried out, and the results analyzed to obtain the scattering function of the medium. Fig.3, refering to a measurement interval of 330 minutes shows 3 curves, each giving the scattering function averaged in one of the intervals 0 - 1°, 1°- 1.5°, 2°- 2.5°.

The figure also shows the time evolution of the extinction coefficient σ of the medium. One can see that when σ increases (decreases) the peak value of $L(\vartheta)$ also increases (decreases), and the width of the forward peak decreases (increases). This effect was apparent during our series of measurements and is related to the evolution of the fog droplets size.

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In press (Applied Optics).

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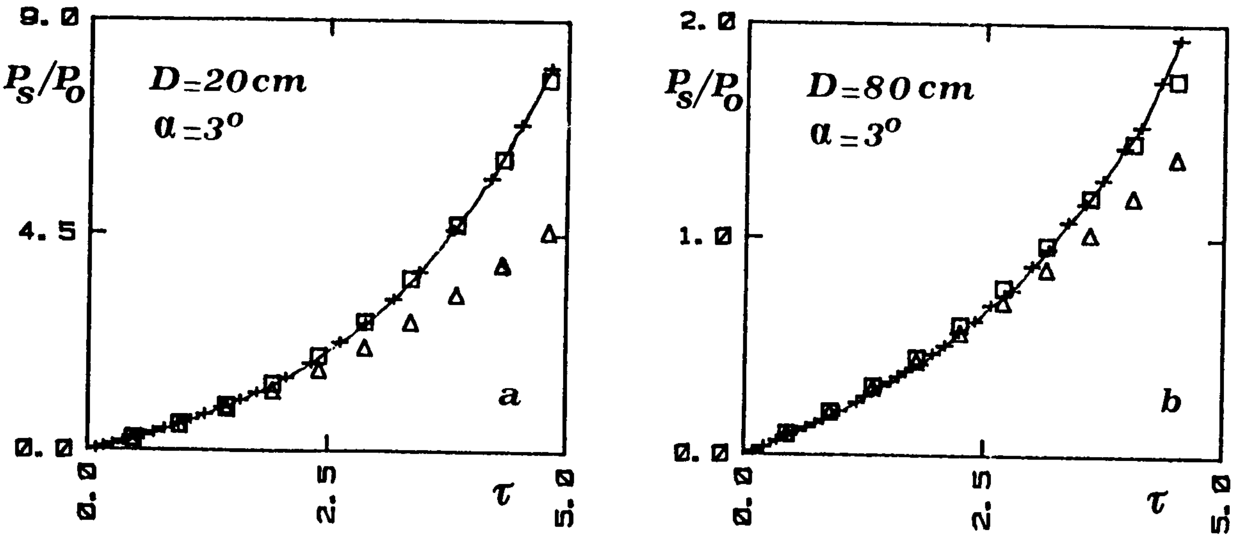

Fig. 1 - Comparison between calculated (squares) and measured (crosses connected by a continuous line) ratios P_s/P_0 between the received scattered power and the direct beam attenuated power. The ratios are plotted versus the optical depth τ. The triangular marks indicate the calculated summed contributions of the first two orders of scattering.
Spheres with average radius 7.85 μm. Receiver's area radius 1 cm.

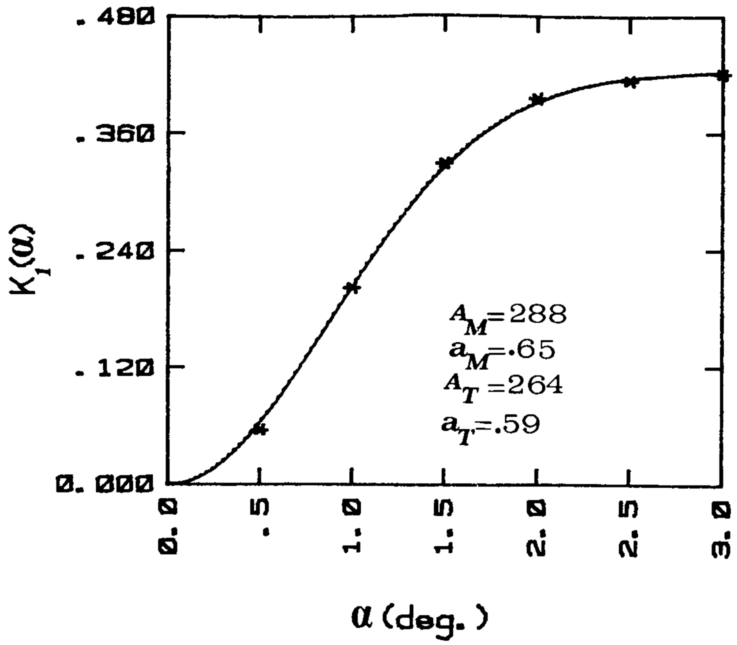

Fig. 2 - Stars: measured values of the coefficient $K_1(\alpha)$ of eq. 1. Continuous line: K_1 calculated by means of a Gaussian scattering function, $L(\vartheta) = A \exp(-a\vartheta^2)$. A_M, a_M: results of the Gaussian parameters best fitting the curve. A_T, a_T: parameters deduced by fitting to results of Mie theory.

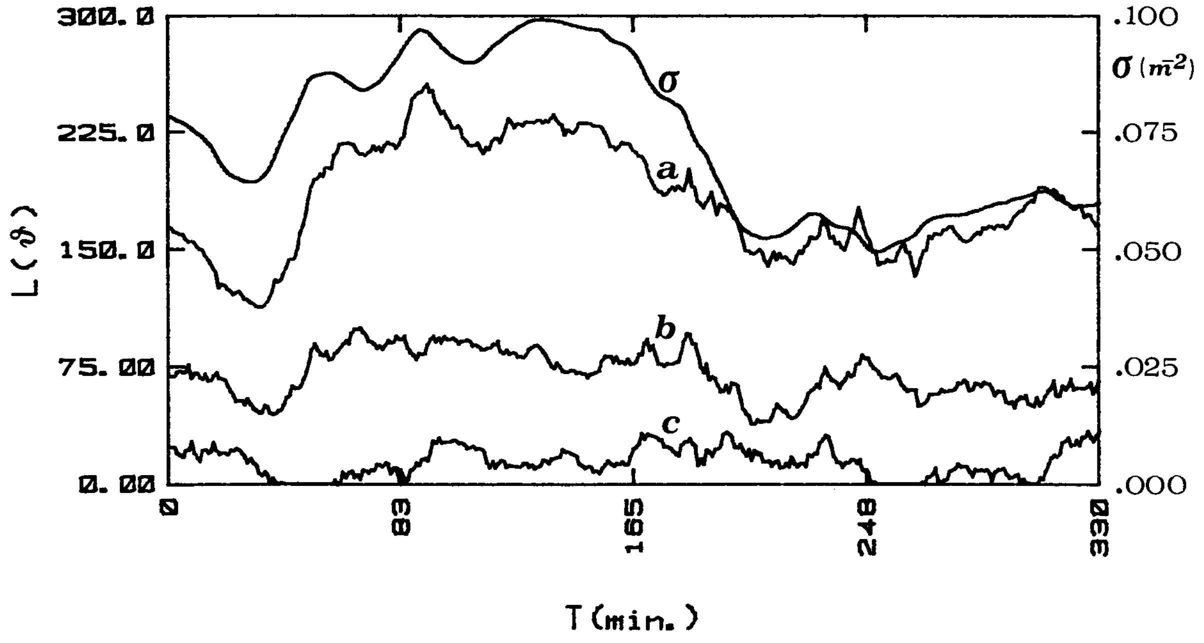

Fig. 3 - Fog measurements during a time interval of 330 minutes. The curves a, b, c show the average scattering function in the intervals: 0-1°, 1°-1.5°, 2°-2.5° respectively, deduced by analyzing the received scattered power. Curve σ shows the measured extinction coefficient.