Sizing of water droplets using the glory phenomenon

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The glory phenomenon is an interference pattern, produced due to the backscattering of light by spherical water droplets. The purpose of this study is to develop a novel technique for sizing of water droplets from its glory intensity pattern. By using the near backscattering angles, the emitter and receiver can be located at the same angle. This makes the technique very compact and extremely useful in applications where only one optical window is available.

The glory phenomenon

The perpendicular and parallel components of the far-field intensity, \( I_1 \) and \( I_2 \) respectively, were calculated from the Lorenz-Mie theory [2, 3] for a single water droplet with size parameters between 100 and 10000, at scattering angles between 175° and 180°. Fig. 1 shows \( I_1 \) and \( I_2 \) for a droplet with size parameter of \( x=100 \) and \( x=3000 \).

On the contrary, when the droplet is large, the low frequencies are used to obtain the size parameter of the droplet. In this case, the scattering angles of two consecutive peaks in the low-frequency oscillations of the glory intensity can be related to the size parameter by adding phase information to the geometrical optics rays suffering either one external or one internal reflection.

Good agreement was found between this model and the Lorenz-Mie theory, for both small and large droplets.

Experimental investigation of the glory produced by large droplets

A preliminary experiment was set up in order to validate the geometrical optics model for large droplets. In order to do this, a single water droplet was suspended from a syringe and illuminated with a He-Ne laser. The light scattered by the droplet at scattering angles between 175° and 180° was recorded with a CCD camera. A horizontal profile of the glory image was analyzed in order to extract the scattering angle of two consecutive peaks to obtain the size parameter using the model derived in this paper.

A good correlation was found between the size parameter calculated using the geometrical optics model and the one from shadowgraph measurements.

Conclusions

The good agreement found between the geometrical optics model and the Lorenz-Mie theory encourage further investigation of this technique, both for smaller droplets, where an experimental investigation should still be performed, and for multiple droplets.

References