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Fine structures of the near-backward scattering of single spheroid droplets: characterization of size and temperature

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The measurement of size and temperature of large droplets is a key issue for a wide range of mechanical-engineering problems [1, 2]. With elastic light scattering techniques, one major difficulty to obtain droplet temperature is the relatively weak temperature dependence of the refractive index of most liquids. However, it is believed that a temperature resolution of a few degrees is in the range of the so-called rainbow thermometry technique (RDT)[3-7]. In the recent years, most efforts to improve the accuracy of RDT were put on the influence of droplets internal refractive index gradients, probably because rigorous light scattering models were available [8]. Cleary, with large droplets, the major problem is that they are rarely perfectly spherical. Their near-backward scattering always deviates significantly from the one predicted by the classical Lorenz-Mie theory. Although this is not a panacea, the oblate shape is a better shape model for large droplets. However, the near-backward scattering of oblate droplets do not only exhibit elliptically curved primary rainbow fringes, but also complex patterns especially resulting from the emergence of new cusp caustics [9, 10]. Geometrical ray-models [10-13] allow predicting the main features of the primary fringes associated to these caustics, but not the fine structure of the scattering diagrams that are so crucial for accurate characterization of the droplets.

Recently, the present authors have introduced the Vectorial Complex Ray Model (VCRM) [14] whose formalism allows predicting these fine structures. The goal of the present paper is to report the first experimental validation and application of VCRM for the characterization of large oblate droplets that are trapped in an acoustic field.

The RDT setup is formally identical to the one of a critical-angle diffractometer [15, 16], except that the detection optics is set in the primary rainbow angle region. A shadowgraph imaging system (SIS) is used for size measurement comparisons. While to retrieve the droplet characteristics from RD data and VCRM predictions, a simple unconstrained least-square minimization procedure is used.

It turns out that VCRM predictions fit very well the experimental scattering patterns, except at the immediate vicinity of the singularities associated to the primary rainbow and hyperbolic-umbilic diffraction catastrophe [9, 10]. For droplets nearly the same volume-equivalent sphere radius $137.47\pm0.21\mu$m (size parameter>2800) and aspect ratio ranging from 0.8938 up to 0.9875, the mean difference and RMS in the response of the SIS and RDT were found to be only of $0.05\pm0.17\mu$m, $-0.09\pm0.35\mu$m and -0.001 ± 0.003 for, respectively, the droplet major and minor radii, and the corresponding aspect ratio. RD measurements show that the droplet temperature continuously increases during the experiment. The droplet temperature fluctuations were estimated to be about $\pm2°$C (i.e. refractive index variations: ±0.0002).

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