Laser light scattering particle sizing: inherent limitations and effects of optical model selection, unknown refractive index, and irregular particle shape

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Measuring the size distribution of dust particle clouds is of interest in many scientific and technological fields. Inversion of the phase function measured by laser light scattering (LLS) [2] is one of the most widely used sizing methods, owing to its speed, bulk-representative sampling, suitability for a wide range of sizes and materials and ease of use [2]. In this presentation, we briefly review different aspects of LLS, including instrumental features, inversion techniques and scattering models. We show that the LLS method using the Mie optical model retrieves robustly size distributions of spherical particles for particle radii $r \geq 0.2$ μm, while the upper limit is determined by how close to zero scattering angle (θ) the measurements are performed. The retrieval of size distributions is very sensitive to overestimating the absorption coefficient and underestimating the real part of the refractive index in the small particle range for $r < 10$ μm. The Fraunhofer model can be used in a restricted scattering angle range ($\theta < 6°$) and is valid for very absorbing particles for sizes below 1 μm, while for non-absorbing particles the retrieved size distributions are reliable for $r > 3$ μm.

Because real world particles are in general irregular, we focus on the application of LLS to the sizing of irregularly-shaped particles (agglomerate debris model [3]) in a critical range where particle size and analysis wavelength are of the same order (0.1 μm – 3 μm). The phase functions modelled with the DDA method in this size range show heavy entanglement of size, refractive index and irregularity effects. It is shown that in this size range reasonable retrievals are obtained for distributions dominated by particles closer to the upper limit of the range (e.g., power-laws with exponent $p > -2.5$), where size remains the dominant effect. In general, irregularity results in narrower forward scattering peaks and lower scattered intensity at side angles compared to spherical analogs. Diffuse scattering inside irregular particles manifest itself in the phase function as an apparent absorption. As a consequence, LLS retrieves distributions with larger effective radius and higher effective absorption coefficient and/or a lower real refractive index. It can be inferred that the use of the scattering pattern of model particles (spherical or irregularly-shaped) with an internal structure different to that of the real samples under study in order to determine the real and imaginary parts of their refractive index may result in wrong estimates, e.g. a higher absorption coefficient if the model particles are more compact. Accounting for this requires a characterization of the additional absorption and extended size range as a function of the internal structure (packing density) of the particles under study.

References

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Preferred mode of presentation: Oral