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Shaped beams and non-spherical particles with FIT and GO

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Current and future in-situ measurement devices for non-spherical particles such as ice crystals often rely on laser beams as sources of illumination. Examples for such devices include the Small Ice Detector (SID) [1] used in various field measurement campaigns. In many cases these laser beams display a Gaussian TEM_{00} profile of intensity which may or may not influence the measurement results to a significant degree. In order to exclude the shaped beam as a source of systematic error in the calibration of such an instrument, light scattering models are needed, which take into account the influence of a shaped beam on the field scattered by a non-spherical particle.

Appropriate models have been developed, based on a two-stage approach that takes into account the disparate length scales of scattering particle and field wavelength. At small Mie parameters a numerical model based on the finite integration technique (FIT) [2] is used, while for large size parameters the common geometrical optics (GO) approximation has been adapted to allow the consideration of a shaped beam as an incident field. The finite integration technique itself is a finite volume method originally developed by Weiland. It allows the computation of numerically exact solutions of Maxwell's equations and is widely used in a computational electromagnetics context. Both methods have been validated against Mie and Generalized Lorenz Mie (GLMT) calculations as well as ray tracing methods for the non-spherical case. As an application case, the scattering of a Gaussian beam by a hexagonal prism representative for an ice crystal has been chosen. Numerical results of immediate importance for the experimentalists are the scattered intensity distribution in the forward hemisphere, the phase function and the sensitivity of the phase function to variations in particle position and surface roughness as well as particle dynamics.

[1] Z. Ulanowski, P. H. Kaye, E. Hirst, R. S. Greenaway, R. J. Cotton, E. Hesse, C. T. Collier: Incidence of rough and irregular atmospheric ice particles from Small Ice Detector 3 measurements, Atmos. Chem. Phys. 14 (2014)

[2] T. Weiland: Eine Methode zur Lösung der Maxwellschen Gleichungen für sechskomponentige Felder auf diskreter Basis, AEÜ, Band 31, Heft 3, pp. 116-120 (1977)