

Decomposition of objects for light scattering simulations with the null-field method with discrete sources

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Abstract

The null-field method with discrete sources (NFM-DS) is used for the simulation of the light scattering by elongated particles. These particles can be decomposed into several identical parts with a small aspect ratio. The T-matrix computed for a single part is used to compose the T-matrix for the whole particle. For verification purposes the light scattering distributions computed with NFM-DS are compared with results from DDA (discrete dipole approximation).

1 Introduction

Computations of light scattering by elongated particles are needed in various scientific branches such as astrophysics, atmospheric science and especially in optical particle characterization. In optical particle characterization there is interest to detect airborne fibrous particles like mineral, glass or asbestos fibres, which are considered to be serious health hazards. Here high aspect ratios are of special interest and so it is required that a light scattering simulation algorithm can handle them.

The null-field method with discrete sources (NFM-DS) is suitable for the simulation of light scattering by particles with high aspect ratios, like finite fibres or flat discs. The method also can be used for computation of the T-matrix of composite objects [1]. Therefore, it is possible to compose complex particles from basic parts for which the T-matrix is already known.

In this work we examine a new approach to compute scattering by fibres and we will present computational results. The method is described briefly in the next chapter.

2 Null-Field Method with Discrete Sources for Composite Objects

Using discrete sources we can compute scattering by a single fibre having a high aspect ratio. But to compute scattering by two long fibres which stick together in some way would be a multiple scattering problem and to solve this problem using a standard multiple scattering concept combining the T-matrices of both fibres would not be possible because the circumscribed spheres of both fibres would intersect. Also other computational approaches such as DDA, FDTD and related methods might be problematic because if the fibres are not aligned parallel to each other this would blow up the computational domain and increase computer time tremendously.

To overcome this problem we developed a multiple scattering method based on decomposition into basic parts [2]. Each fibre is decomposed into basic parts having a small size parameter and the full scattering problem is solved by combining the T-matrices of all those parts.

In this work we would like to show the feasibility of this new method. It is important to make a computational analysis, because the circumscribing spheres of the basic parts show

intersecting volumes, even if comparatively low. The NFM-DS simulations are verified with DDA simulations (DDSCAT) [3].

3 Simulations results

In the following two examples are presented fibres of circular section composed of four identical basic parts. Each section is a short cylinder of circular cross section.

In Figure 1 the differential scattering cross section (DSCS) of a fibre with the size parameter $kh = 8$ is shown, where k is the wave number $2\pi/\lambda$ and h is the length of the fibre. The diameter of the fibre corresponds to $kd = 2$. The index of refraction values $m = 1.5$. The fibre is composed of four equal sized cylinders with $kh = 2$ and $kd = 2$. The rotational axis of the fibre is aligned on the z-axis. The plane wave is incident along the z-axis and the scattering diagram is plotted on the x-y plane both for incident p- and s-polarization.

The comparison with a corresponding DDA simulation shows good agreement in the DSCS. Small deviations for the p-polarization indicate that the influence of the intersecting circumscribing spheres can not be neglected.

Further simulations with smaller objects but similar configurations show even better or almost perfect agreement between NFM-DS and DDA. It seems obvious that there is an upper limit in size of the composed objects for which the effect of the intersecting circumscribing spheres must not be neglected.

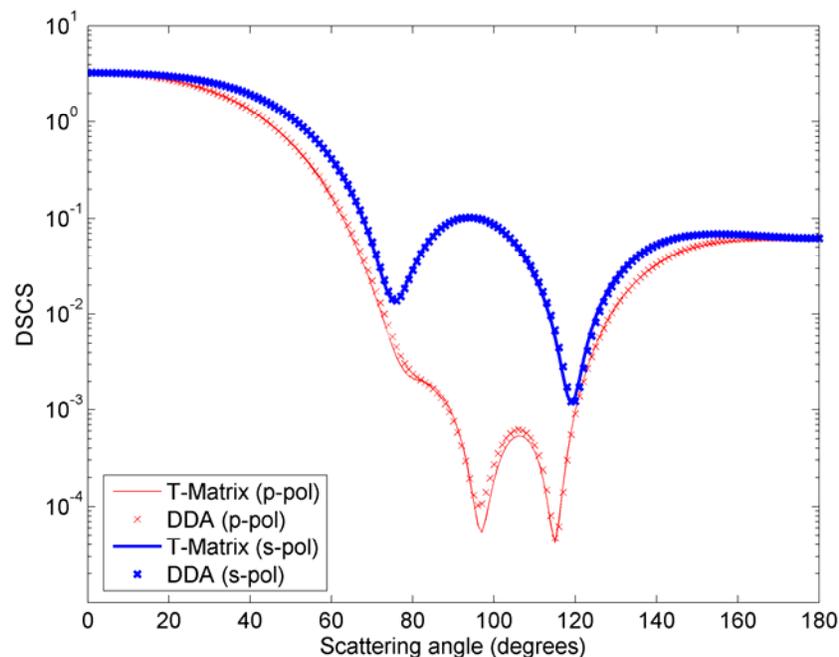


Figure 1: DSCS of a cylindrical particle (length $kh = 8$; diameter $kd = 2$; $m = 1.5$). Comparison of T-matrix and DDA simulations. The T-matrix is composed of 4 identical T-matrices of smaller cylinders with $kh = 2$.

In Figure 2 the differential scattering cross section (DSCS) of a fibre with the size parameter $kh = 16$ is shown. The diameter of the fibre corresponds to $kd = 4$. The index of refraction values $m = 1.5$. The fibre is composed of four equal sized cylinders with $kh = 4$ and $kd = 4$. The rotational axis of the fibre is aligned on the z-axis. The plane wave is incident along the z-axis and the scattering diagram is plotted on the x-y plane both for incident p- and s-polarization.

The comparison with a corresponding DDA simulation shows only good agreement in the forward scattering angle range from 0° to 80° . Strong deviations for both the p-polarization and the s-polarization show the limits of the method of composing the T-matrix from basic parts if the circumscribing spheres of the basic parts intersect.

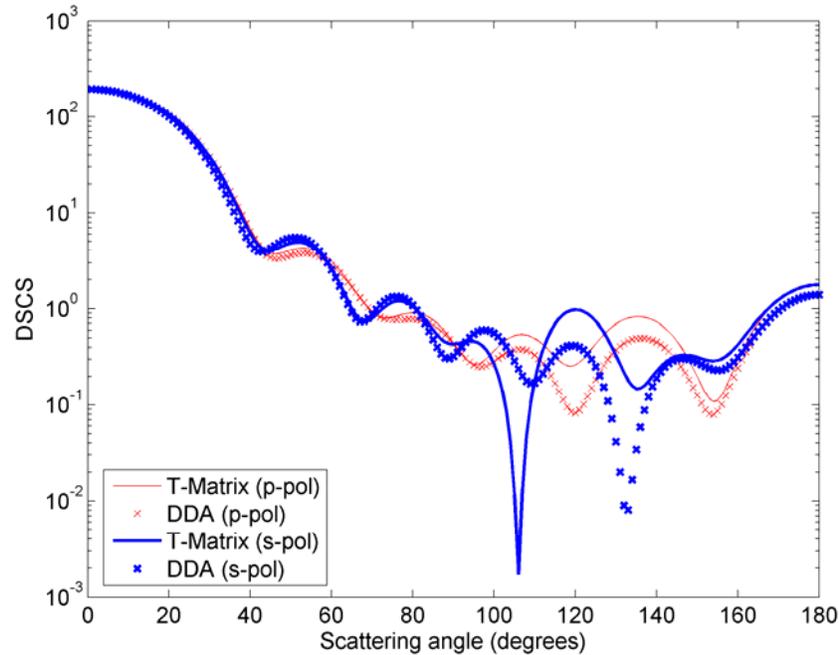


Figure 2: DSCS of a cylindrical particle (length $kh = 16$; diameter $kd = 4$; $m = 1.5$). Comparison of T-matrix and DDA simulations. The T-matrix is composed of 4 identical T-matrices of smaller cylinders with $kh = 4$.

4 Conclusion

It has been shown that the NFM-DS can be used to compute light scattering by composite objects. This makes possible the computation of the light scattering for even more complex objects like torus- or helix-shaped particles. The first computations for simple fibres show the need for further investigations to verify the range of validity of the method.

Acknowledgments

We would like to acknowledge support of this work by Deutsche Forschungsgemeinschaft DFG.

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