Scattering matrix of semi-infinite scattering media

Alexey A. Shcherbakov

ITMO University, 49 Kronverksky, 197101 Saint-Petersburg, Russia (alexey.shcherbakov@metalab.ifmo.ru)

Simulations of light scattering from strongly scattering media are important for many applications ranging from mineralogy to planetary science. When the refractive index contrast is sufficiently large, and the scale of inhomogeneities is comparable to the wavelength of the incident radiation, an accurate prediction of spectral angle-resolved reflection requires a rigorous numerical solution of Maxwell's equations. A number of approaches dealing with this problem have been investigated, many of them analyzing bounded partitions of scattering media. Thus, often the transition from a single-scattering part to a semi-infinite bulk inhomogeneous material represents a considerable problem.

To cope with the problem we consider two approaches based on the Fourier space S-matrix methods for planar diffractive structures. A thick layer bounded by two planes is represented as an infinite crossed grating. When periods of such grating are taken to be sufficiently large in comparison with both the wavelength and the inhomogeneity scale, and the material and geometric composition of each period corresponds to those of real media, an impact of the periodicity on the reflection characteristics can be made negligible. Simultaneously, this artificial periodicity allows us to apply analytically known S-matrix components of thin grating slices [1] and rigorously calculate the whole layer S-matrix.

As a first approach, the S-matrix composition algorithm can be used to repeatedly double S-matrix (and double the layer thickness respectively) until convergence of reflection parameters to a given accuracy. As a second approach, the Ambartsumian's invariance principle developed within the radiative transfer theory [2,3] can be applied on the basis of *ab initio* S-matrix calculations. The principle consisting in the invariance of reflective properties of a semi-infinite medium upon addition of a finite thickness layer yields a matrix Riccati equation. In this contribution, both theoretical formulations of the methods and analyses of their numerical behavior and bottlenecks will be discussed.

References

[1] Shcherbakov, A. A., Yu. V. Stebunov, D. F. Baydin, *et al*., 2018: Direct *S*-matrix calculation for diffractive structures and metasurfaces. *Phys. Rev. E* **97**, 063301.

[2] Ambartsumian, R., 1988: *A life in Astrophysics. Selected Papers of V. A. Ambartsumian*. Allerton Press, New York.

[3] Plass, G. N., G. W. Kattawar, F. E. Catchings, 1973: Matrix operator theory of radiative transfer. 1: Rayleigh scattering. *Appl. Opt.* **12**, 314–329.

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