Scattering simulation of generalized Bessel beams by arbitrary particles

S. A. Glukhova[1,2*] and M. A. Yurkin[1,2]

[1]*Voevodsky Institute of Chemical Kinetics and Combustion, SB RAS, Institutskaya 3, 630090 Novosibirsk, Russia*
[2]*Novosibirsk State University, Pirogova 2, 630090 Novosibirsk, Russia*
[*]*corresponding author's e-mail: stefgluhova@gmail.com*

Introduction

Bessel beams are at the frontier of different types of structured light with orbital angular momentum. These beams have numerous applications in such fields as optical manipulation (tweezing), material proceeding, imaging, etc. In many physical problems it is important to take into account the scattering of Bessel beams, which is much better studied for particles with simple symmetries than for arbitrary ones. Moreover, there are a variety of existing types of Bessel beams that have been barely named [1], with neither a complete picture nor clear relations between them. In this regard, this work has two goals: the classification of various types of high-order vector Bessel beams and the development of capability to simulate scattering of any such beam by an arbitrary particle using the discrete dipole approximation.

Results

Vector Bessel beams can be presented in several different forms or types. These types differ by their polarizations, field, and energy configurations. Among them are beams with circularly symmetric energy density (CS type), with transverse electric and magnetic fields – TE and TM types, respectively, and LE and LM – beams with linear polarizations of electric and magnetic fields, respectively. In order to classify them, we developed a new description of various polarizations through the 2x2 matrix **M**, associated with the transverse Hertz vector potentials. This approach clarifies the relations between all Bessel beam types and their polarizations. Also, within this framework, we managed to relate beams of different orders using the rotation and duality operators, which action corresponds to simple transformations of the matrix **M**. We have implemented all standard Bessel beam types as well as a generalized Bessel beam specified by a matrix **M** (4 complex values) in ADDA package [2]. We successfully validated this implementation against the reference results of GLMT for spheres [3]. Currently, it is available at a separate fork of ADDA: https://github.com/stefaniagl/adda.

In conclusion, now it is easy for anyone to simulate the scattering of various Bessel beams by particles with arbitrary shape and internal structure. The obtained theoretical results clarify the general picture and relations between various types of Bessel beams. Similar considerations can potentially be applied to other complex light beams.

References

[1] J. J. Wang, T. Wriedt, J. A. Lock, and Y. C. Jiao, *General description of transverse mode Bessel beams and construction of basis Bessel fields*, J. Quant. Spectrosc. Radiat. Transf., 195:8–17, 2017.
[2] M. A. Yurkin and A. G. Hoekstra, *The discrete-dipole-approximation code ADDA: capabilities and known limitations*, J. Quant. Spectrosc. Radiat. Transf., 112:2234–2247, 2011.
[3] Z. Chen, Y. Han, Z. Cui, and X. Shi, *Scattering of a zero-order Bessel beam by a concentric sphere*, J. Opt., 16:055701, 2014.