EPSC Abstracts
Vol. 11, EPSC2017-554-1, 2017
European Planetary Science Congress 2017

Experimental light scattering with a novel Mueller matrix scatterometer

A. Penttilä (1), G. Maconi (1), **I. Kassamakov** (1), M. Gritsevich (1), P. Helander (1), T. Puranen (1), A. Salmi (1), E. Hæggström (1), and K. Muinonen (1,2)
(1) Department of Physics, University of Helsinki, Finland, (2) Finnish Geospatial Research Institute FGI
(antti.i.penttila@helsinki.fi)

Abstract

We describe a setup for measuring the full angular Mueller matrix profile of a single mm- to µm-sized sample, and verify the experimental results against a theoretical model. The scatterometer has a fixed or levitating sample, illuminated with a laser beam whose full polarization state is controlled. The scattered light is detected with a combination of wave retarder, linear polarizer, and photomultiplier tube that is attached to a rotational stage.

1. Introduction

Measuring scattering properties of different targets is important for material characterization, remote sensing applications, and for verifying theoretical results. Furthermore, there are usually simplifications made when we model targets and compute the scattering properties, e.g., ideal shape or constant optical parameters throughout the target material. Experimental studies can help us in understanding the link between the observed properties and computed results.

Experimentally derived Mueller matrices of particles can be used as input for larger-scale scattering simulations, e.g., radiative transfer computations. This method allows us to bypass the problem of using idealized model for single-particle properties. There are publicly available studies of the scattering properties of particles, e.g., the Granada light scattering database [1]. With our scatterometer, we aim to offer similar material for single, small (down to µm-scale) targets. While other sources usually offer ensemble- and orientation-averaged particle properties, we will be able to measure individual particles with controlled or known orientation.

2. Scatterometer

The measurement can be done in several colors in the visual band. The measurement head comprises a combination of wave retarder, linear polarizer, and photomultiplier tube. One or several of these heads are attached to a rotational stage, so that a range of scattering angles can be covered. The whole system is divided into two chambers that are divided by partition walls. The walls are covered with non-reflecting fabric with only a small pinhole for the incident beam to avoid excess reflections. All the optical components shaping the incident beam are seated in the right chamber (b in Fig. 1), and the scatterer and the detectors are located in the left chamber (a in Fig. 1). Furthermore, there is a second pinhole on the leftmost wall for the forward beam to be guided out from the measurement chamber and into a beam trap.

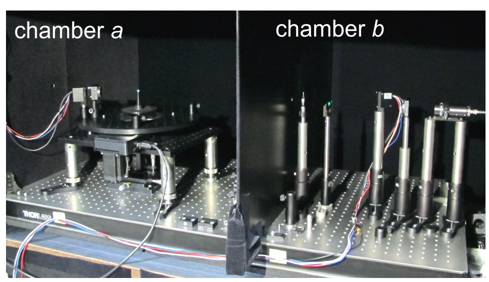

Figure 1: Image of the current development version of the scatterometer. The sample is standing on a static conic pedestal in this image, and not levitated with the ultrasonic device.

The incident beam is generated with a tunable multimode Argon-krypton laser, with 12 selectable wavelengths ranging from 465 to 676 nm. The laser is placed outside the chambers to avoid excess heat and vibration, and the light is brought in with an optical fiber. In chamber b (Fig. 1), the beam is expanded, diffused, and shaped after the fiber output to create a speckle-free, collimated constant-intensity beam. The polarization state of the beam is controlled by rotation-controlled linear polarizer and wave retarder. The incident beam is monitored by a photomultiplier tube (PMT) detecting the secondary reflection intensity from the system before the measurement chamber.

The incident beam encounters the scattering target in chamber a (Fig. 1). The target will be controlled with an advanced ultrasonic levitator. The levitator comprises several individually-controlled amplifiers and outputs to generate a complex ultrasound field. The shape of the field can be modified to generate a stable trap or even vortex forces in the trap. We aim to be able to control the target orientation in the trap with the ultrasound field, and the target position and orientation can be monitored using a high-speed camera attached to the system. The ultrasound trap is still under development, and the first tests presented here are executed with the target seated on a thin solid cone pedestal, or with a more simple singe-amplifier levitator.

The detectors, Hamamatsu micro-PMTs, are mounted radially towards the target on a rotational stage. The stage is controlled by a rotation motor with an accuracy of 15'. The current 150-mm radius allows measuring all azimuthal angles except for $\pm 4°$ around the backward scattering direction. With several detectors we can do a simultaneous multi-angle measurement, and by rotating the stage we can increase and sample more densely the angle range. The small physical dimensions of the new micro-PMTs allow us to seat many detectors side-by-side without compromising in the distance to the target too much.

3. Results

We have conducted the first calibration measurements with the scatterometer. The first set of measurements are done with one wavelength at 514 nm, with one detector that is rotated over the sample, and with linear polarizers only. The sample, which is a N-BK7 clear glass sphere from Edmund Optics, diameter $d = 5$ mm and refractive index $n = 1.5$, is mounted on a thin black cone (static sample).

We verify the first measurement set by comparing the angular scattering profile against the theoretical results computed using Mie theory. The Mie results are averaged over a small angular window to accommodate the actual acceptance angle of the detector. For the clear sphere, the symmetries require that $M_{11} = M_{22}$ and that $M_{12} = M_{21}$. In Fig. 2 we can see that the symmetries hold quite well. Also, comparing to model (Mie) results show quite nice agreement.

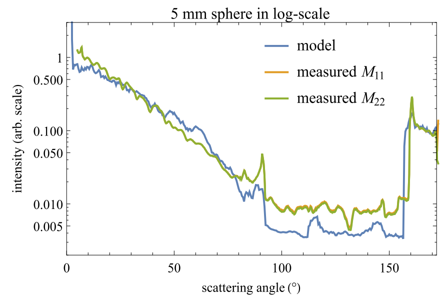

Figure 2: Measurements and model for 5-mm clear static sphere, diagonal elements M_{11} and M_{22}. The measured elements overlap, so the measured M_{11} curve is behind the measured M_{22}.

Acknowledgements

The authors acknowledge the financial support from the European Research Council, Advanced Grant No. 320773 entitled Scattering and Absorption of Electromagnetic Waves in Particulate Media(SAEMPL).

References

[1] O. Muñoz, F. Moreno, D. Guirado, D.D. Dabrowska, H. Volten, and J.W. Hovenier. The Amsterdam–Granada light scattering database. *J Quant Spectrosc Radiat Transf*, 113(7):565–574, 2012.