OPTICAL PROPERTIES OF LEVITATED PARTICLES OBTAINED USING A 4π SCATTEROMETER.

G. Maconi[1], P. Helander[1], M. Gritsevich[1,2], A. Penttilä[1], I. Kassamakov[1], T. Puranen[1], A. Salmi[1], E. Hæggström[1], and K. Muinonen[1,3], [1] Department of Physics, University of Helsinki, P.O. Box 64, 00014 Helsinki, Finland, [2]Ural Federal University, Ekaterinburg, Russia, [3]Finnish Geospatial Research Institute, Geodeetinrinne 2, 02430 Masala, Finland.

Background: The primary purpose of the scatterometer is to aid in verification of the state-of-the-art light scattering models by providing robust experimental data for well-characterized samples. Non-destructive measurements are also important for characterizing unique and valuable samples, such as e.g., cosmic dust and samples returned from Solar System objects.

One of the first scatterometry setups for small particle characterization was built in Arizona [1]. The system was used to characterize 110 nm diameter latex spheres. A more recent system was built in the Netherlands [2], and further developed at the IAA cosmic dust laboratory, Granada, Spain [3], to measure scattering properties of irregularly shaped mineral aerosol samples. These systems differ from our instrument in that they measure the statistical average of a group of particles.

The scatterometer: We have designed and built an orientation-controlled scatterometer, i.e., an instrument for precise polarimetric (full Mueller matrix) measurement of light scattered by a mm- to μm-sized sample held in place by sound [4]. The position and orientation of the sample inside the scatterometer are controlled by the multichannel acoustic levitator. This allows non-destructively measuring light scattering in any solid angle, giving us a full 4π measurement. Additionally, high speed camera monitoring the sample allows to make a photogrammetric 3D shape characterization of the sample while measuring its optical properties.

System design: The scatterometer comprises four parts, based on their function: the light source, the sample levitator, the analyzer, and the monitoring camera:

- The light source is a laser-stabilized arc lamp producing white light, which is then filtered by a line filter and polarized by a linear polarizer. A reference photomultiplier tube (PMT) is used for monitoring the beam intensity, and the signal can be used to calibrate the observed signal power level.
- The sample levitator is custom built and features 400 transducer elements, grouped into 28 phase controlled channels. The resulting two hemispherical phased arrays produce an asymmetric acoustic trap which holds the sample in place at an adjustable orientation (heading, pitch and roll).
- The analyzer comprises a PMT with an integrated solid state high speed shutter, a motorized quarter wave plate, a motorized linear polarizer, and a motorized shutter. It is mounted on a large, motorized rotation stage, allowing it to scan the scattered light with an angular accuracy of 15'.
- The camera monitoring system allows to verify the stability of the ultrasonic levitation and orientation control. It features a high speed camera and near infrared LED illumination.

Research methods and materials: The system is fully automated using LabVIEW, including the FPGA-based multichannel data acquisition, the motorized control of shutters, polarizers and quarter wave plates, and the instrument's user interface. Before each measurement, the sample is imaged while rotating it one revolution around each of the x-, y-, and z-axes, producing enough image data for a photogrammetric estimation of the 3D shape of the sample. After the initial imaging phase, the sample is scanned in sweeps by the photomultiplier tubes (PMTs). Each sweep provides a circular set of data for one orientation of the sample and one polarization configuration.

To cross-validate theory and experiment, we have studied well-defined samples that can be modelled computationally and are also commercially available. The 3 mm glass spheres are easy to model using the Mie scattering and provide a baseline for what accuracy we can expect working with the system. We have also measured agglomerates composed of 500 nm silica spheres, which are more comparable to real-world mineral dust samples, while still being very well defined for theoretical computations. These samples were additionally compared to the samples composed of irregular silica grains (0.5 to 10 μm) which can be considered a grains of the natural mineral dust.

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