Measuring The Volume Scattering Function Using the Lisst-100

The LISST-100 instrument can be used to measure the volume scattering function at scattering angles from 0.097 to 19.5 degrees (1.70 to 340 mrad)

SEQUOIA SCIENTIFIC, INC. APPLICATION NOTE LOO2

The absorption coefficient and the volume scattering function (VSF) are the two inherent optical properties that completely characterize how light propagates through water. Although absorption is now routinely measured, the VSF is rarely measured because of technical difficulties. However, the LISST instrument measures the VSF at scattering angles from 0.1 to 20 degrees. Measurements of the VSF over this range of angles are valuable because, for example, the8y can be used to predict point spread functions, and hence the appearance of underwater objects. The VSF is defined with the help of Figure 1.

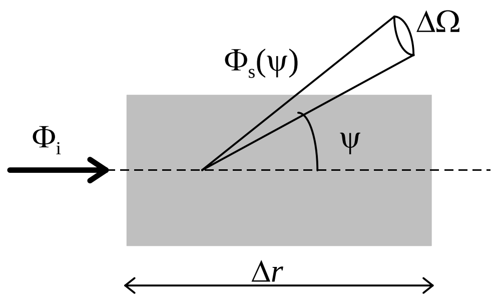

Figure 1: Geometry defining the VSF.

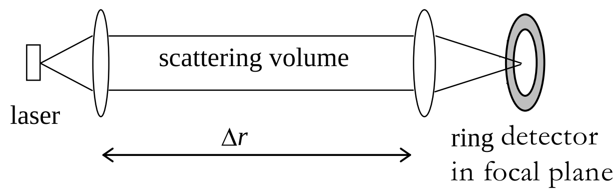

Figure 2: LISST optical layout.

Let a narrow, collimated beam of light of power F_i be incident on a volume of water of thickness D*r*. Some part F_s(y) of the incident power is scattered into a solid angle DW centered on the scattering angle y. Then the VSF is operationally defined by

$$VSF(\psi) = \frac{\Phi_s(\psi)}{\Phi_i \ \Delta r \ \Delta\Omega} .$$

Figures 2 and 3 show how this definition is implemented in the LISST. Figure 2 shows the basic optical layout of the LISST.

A beam is formed by collimating the output of a diode laser. Scattered light is detected by a specially constructed detector consisting of 32 log-spaced rings (plus a center hole which allows passage of the unscattered direct beam, which gives a measurement of the beam attenuation).

As shown in Figure 3, each detector ring collects the light scattered into a particular solid angle DW defined by a narrow range of scattering angles. Note that a given detector ring collects the light scattered into a given y range, regardless of where the scattering takes place along the incident beam.

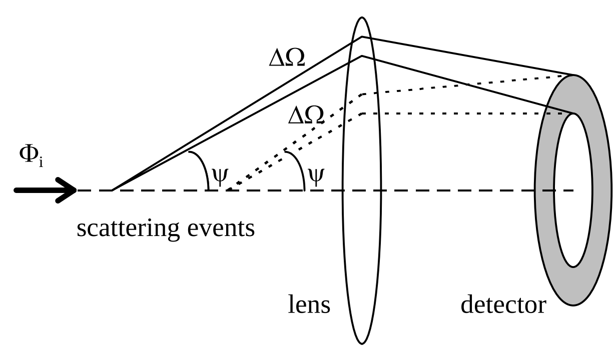

Figure 3: VSF Measurement by the LISST.

To complete the computation of the VSF in calibrated units of m^{-1} sr^{-1}, allowance must be made for attenuation of the scattered light within the water, for losses in the optical system, and for losses in the detector. The quantum efficiency of the detector itself is known only to within an error of about 20 per cent, which is the dominant error in the calibration. Errors due to multiple scattering in the sample volume are small except in extremely turbid waters (beam attenuation > 20 m^{-1}). For many purposes (such as the prediction of image blurring by small-angle scattering) only the shape of the VSF is of interest, and any errors in the magnitude of the VSF are irrelevant.

The solid line of Figure 4 shows the VSF measured on a suspension of polystyrene spheres, which had a nominal diameter of 100 mm (Duke Scientific Corp.; sphere diameter 100±2 mm with a standard deviation of 4.2 mm). The dotted line in Figure 4 shows the corresponding curve as predicted by Mie theory for spheres of exactly 100 mm diameter. The Mie calculations were performed for a unit concentration of particles, and the resulting curve was scaled in magnitude to match the measured VSF. The strong resonances seen in the monodisperse Mie curve almost disappear in the measured VSF because of the spread of sizes of the polystyrene spheres. Except for this expected difference in the curves, the agreement between measurement and theory is excellent over four orders of magnitude in the VSF.

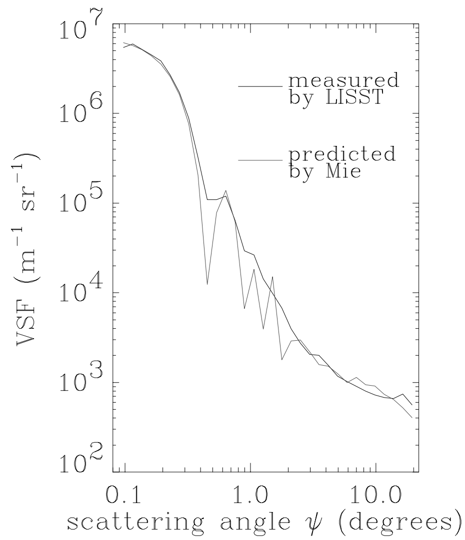

Figure 4: Measured and predicted VSF.

The VSF is the fundamental quantity measured by the LISST. The VSF can be inverted to obtain the size distribution and concentration of the suspended particles causing the scattering (see Application Note 97-01). The particle size distribution and concentration are the quantities of primary interest to most LISST users.

Note finally that the LISST does not use mechanical apertures to define the solid angles, nor does it have any moving parts - such features can be a source of problems in VSF instruments of other designs.

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