A Polarized Scanning Nephelometer for Measurement of Ensemble-averaged Scattering Matrix of Aerosol Particles: Design and Validation

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Motivation

Space based remote sensing platforms have vastly contributed to our understanding of earth's atmosphere by providing data over large temporal and spatial scales. But many of the microphysical retrieval algorithms used are based on assumptions that have not yet been well validated (Dubovik, O. et al. 2000). In situ measurements of the scattering matrix of aerosol particles are central to both the validation of remote sensors (Mishchenko, M. I. et al. 2007) as well as obtaining accurate radiative forcing estimates.

$$\begin{pmatrix} I_{sca}(\theta) \\ Q_{sca}(\theta) \\ U_{sca}(\theta) \\ V_{sca}(\theta) \end{pmatrix} = \frac{\beta_{sca}\cdot\Delta V}{4\pi\cdot r^2}\cdot\overline{\overline{P(\theta)}}\cdot\begin{pmatrix} I_{in} \\ Q_{in} \\ U_{in} \\ V_{in} \end{pmatrix} \qquad \overline{\overline{P(\theta)}} = \begin{pmatrix} P_{11}(\theta) & P_{12}(\theta) & 0 & 0 \\ P_{12}(\theta) & P_{22}(\theta) & 0 & 0 \\ 0 & 0 & P_{33}(\theta) & P_{34}(\theta) \\ 0 & 0 & -P_{34}(\theta) & P_{44}(\theta) \end{pmatrix}$$

Design

In the last decades, Zhao et al. (1999) and his research group designed a prototype polarized nephelometer. In the new version nephelometer, the light source has been designed so that we can have four kinds of polarized light at two different wavelengths (445, 633nm). The structure of detection module has been improved and that allow us to measure the scattering light with a wide scattering angle range of 4° to 170° at an angle resolution of 0.1° . Moreover, the stray light has been reduced by specially designed light traps and apertures. The new version can deduce all the elements of ensemble-averaged scattering matrix of aerosol particles.

Fig. 1 Photograph of the Polarized Scanning Nephelometer.

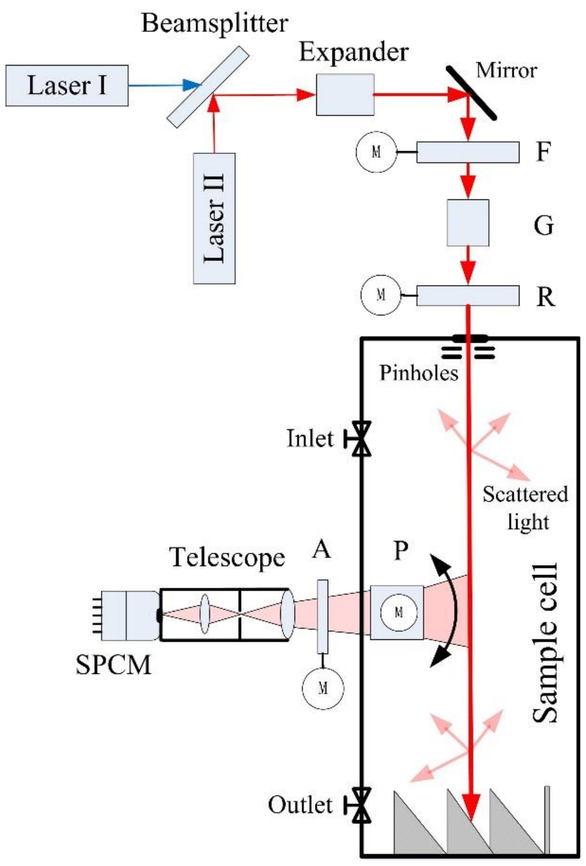


Fig. 2 Schematic overview of the Polarized Scanning Nephelometer. F = filter wheel, G = Glan-Laser Polarizer, R = retarder wheel, P = rectangular prism, A = analyzer wheel, M = motor.

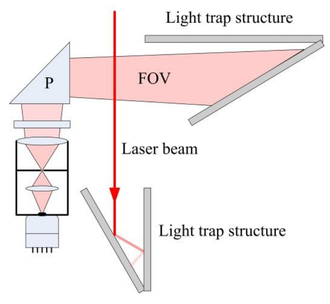


Fig. 3 Schematic overview of the light trap structure.

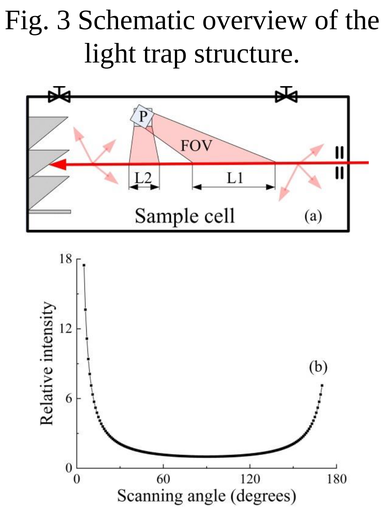
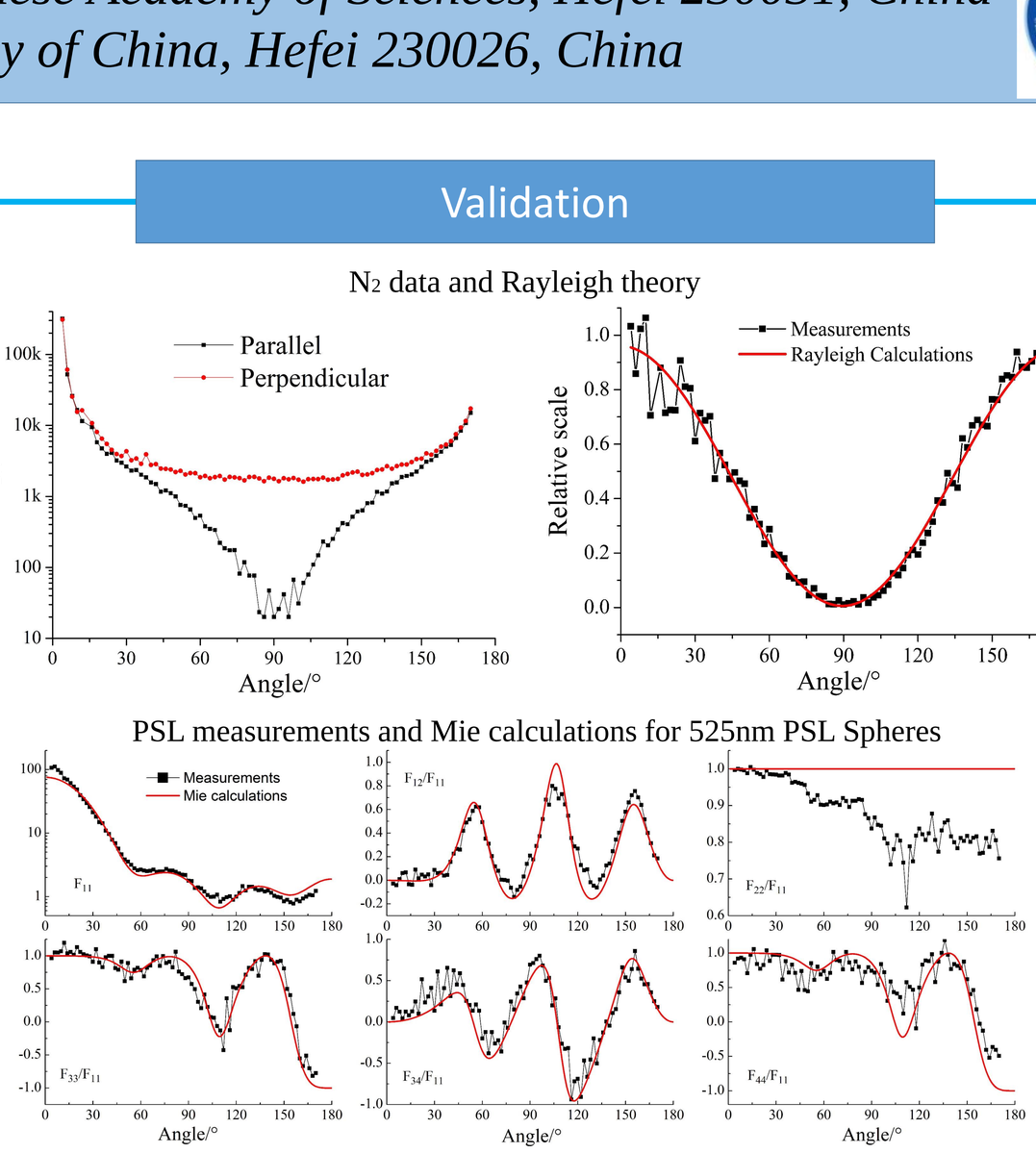


Fig. 4 (a) Schematic overview of sensing geometry of two scanning angles. (b) The relative intensity of SPCM for particles which scatter isotropically.

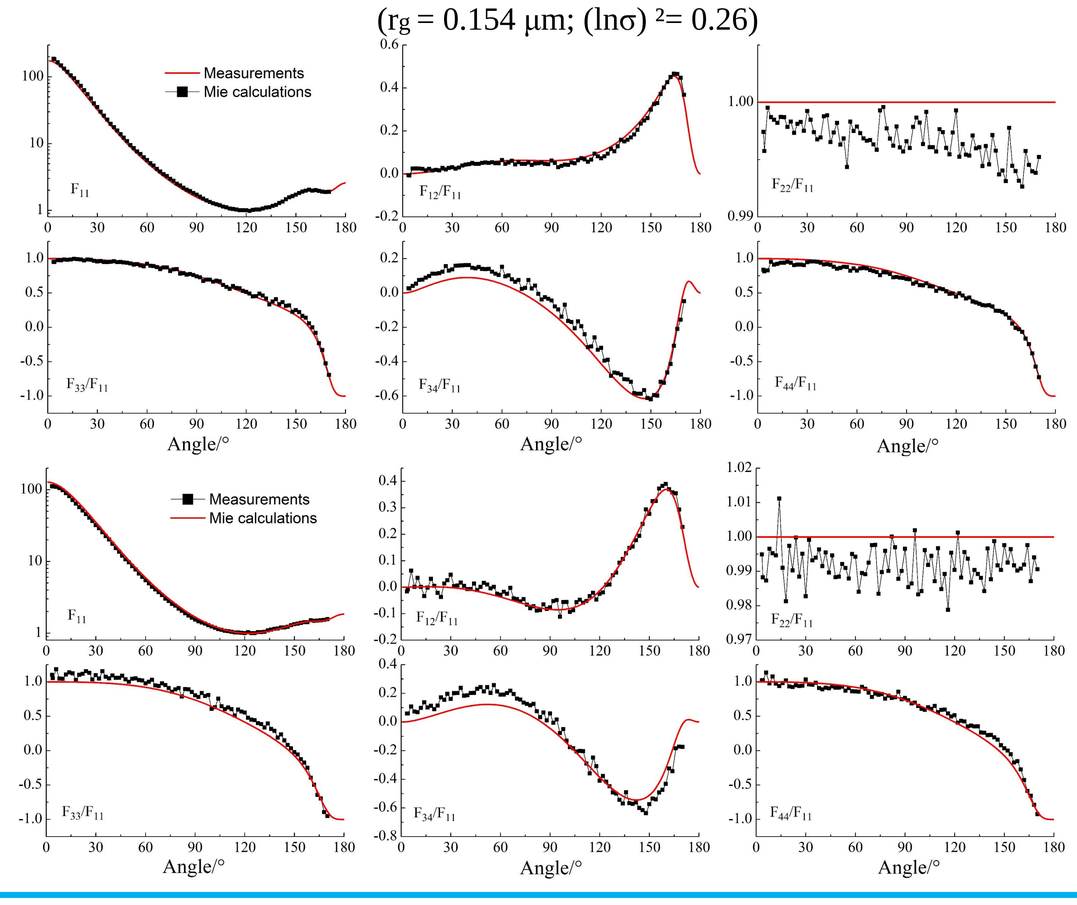
Validation

N_2 data and Rayleigh theory

PSL measurements and Mie calculations for 525nm PSL Spheres



DEHS measurements and Mie calculations at 445nm and 633nm (r_g = 0.154 μm; $(\ln\sigma)^2$= 0.26)



Results and conclusions

- Measurements of nitrogen (N_2) scattering properties are roughly in line with Rayleigh theory. It indicates that stray light has been suppressed to an acceptable level.
- The signal of PSL measurements is only 2~3 times bigger than that of filtered air. The PSL scattering matrix elements are roughly in line with Mie simulations. It indicates that in cases when samples are in very low concentration, the Polarized Scanning Nephelometer can still be able to show the main polarization characteristic of the sample.
- Measurement of Di Ethyl Hexyl Sebacate (DEHS) scattering matrix compare exceptionally well with fitted Mie simulations.