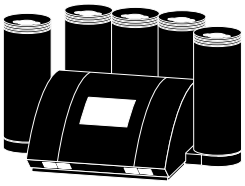
Application Note

Combining the backscattering intensities of blue and IR light sources to get a uniquely defined mean particle size

The particle size is a key parameter when producing particulate materials owing to its dominant effect on various product properties. Thus, particle size determination is of high interest in many fields, such as cosmetic, chemistry, pharmacy, and food industry. As reported, the mean particle size can be easily computed based on Mie theory using the Multiscan technique. However, Mie theory most often gives two values of mean particle size, which impedes the applicability of the method. To solve this problem, DataPhysics Instruments developed a new stability analyser utilising blue light. In this application note, commercial polymer microsphere suspensions with two different particle sizes and concentrations are used as examples to show that a uniquely defined mean particle size can be obtained by utilising the new analyser with blue light working together with the existing system with IR light.

Measurement device
MultiScan dispersion stability analysis system



Measurement method
Optical dispersion stability analysis

Measured quantities
Mean particle size
Transmission intensity
Backscattering intensity

Environmental conditions
25 °C

Samples
Polymer microsphere suspensions

Industries
Cosmetic
Chemistry
Pharmacy
Food

dataphysics

Technique and Method

The MultiScan MS 20 from the German manufacturer DataPhysics Instruments is a dispersion stability analysis system (Fig. 1).[1] It is a measuring device for the automatic optical stability and aging analysis of liquid dispersions, in particular suspensions and emulsions, and the comprehensive characterisation of time and temperature dependent destabilisation mechanisms.

To conduct the measurement, the liquid dispersion is poured in a sample vessel, which is then placed in one of the measuring chambers of the MultiScan MS 20. The MS 20 contains a light source, a detector opposite the light source to measure the transmitted light, as well as a second light source, positioned in a 45 degree angle from the detector, for measuring the backscattered light (Fig. 2). The light sources and detector move up and down along the sample vessel for each measurement so that position-resolved light intensities can be recorded. So far, ScanTowers utilising infrared LEDs (i.e. IR tower) have been widely used for dispersion stability analysis. To broaden the utilisation of MultiScan MS 20 and expand its possibilities to study the stability and aging analysis of liquid dispersions, DataPhysics Instruments has introduced a new type of ScanTower that uses blue LEDs with a wavelength of 470 nm (i.e. Blue tower) recently.

According to Mie theory[2], the mean particle size can be evaluated by using measured backscattering or transmission intensities when the refractive indices of the particle and the solvent as well as the particle volume concentration are known. However, Mie theory leads to two possible values for the mean particle size in most cases. Fig. 3 shows a Mie theory based simulation of backscattering intensity over particle size at a volume concentration of 1% using Blue (blue line) and IR (red line) light sources, respectively. This diagram shows that the backscattering first increases and then decreases with growing particle size. Furthermore, Fig. 3 indicates that one backscattering intensity value corresponds to two different particle sizes. However, if the backscattering intensities measured with the Blue and IR light source are combined, well defined uniquely particle size values can be furnished.

Fig. 1: DataPhysics Instruments stability analysis system MultiScan MS 20 with six independent ScanTowers

Table 1: Properties of the polymer microsphere suspensions

Particle	Diameter	Volume concentration (%)	Refractive index
Polystyrene	110 nm	25	1.59
Polystyrene	1.2 µm	1	1.59

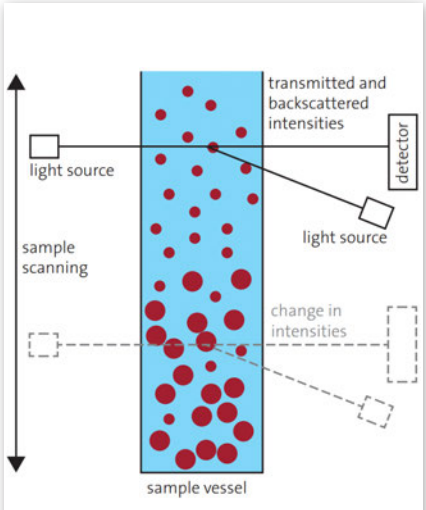


Fig. 2: MultiScan measuring principle

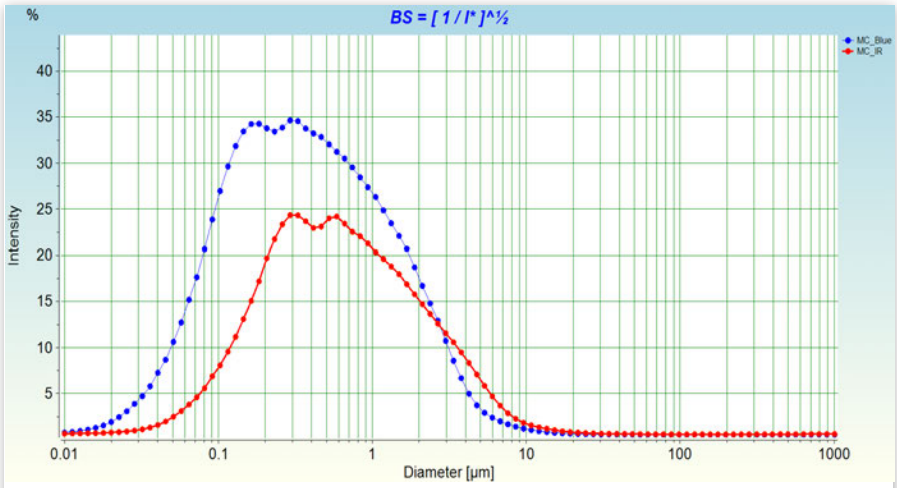


Fig. 3: Simulated backscattering diagram based on Mie theory depicting the change of backscattering intensity over particle size at a volume concentration of 1% using Blue (blue line) and IR (red line) light sources, respectively

Experiment

To compare the accuracy and reliability of measurement data furnished with the Blue tower and IR tower, commercial polymer microsphere suspensions (PMSs) with two particle sizes and concentrations were used in this application note. According to the supplier information sheet, the particle diameters and concentrations of the PMSs are shown in Table 1. The solvent of the polymer microsphere suspensions is water, its density and viscosity are 0.998 g/cm³ and 1.002 mPas at room temperature, respectively. The polymer microspheres are made of polystyrene.

10 ml of each PMS was poured in a transparent glass vial and measured at T = 25 °C every 13 seconds for 1 minute. The measured zone is between 0 mm (bottom of the glass vial) and 57 mm (top of the glass vial).

Results & Discussion

The backscattering intensity of all samples stayed constant during the measurement. Fig. 4 shows backscattering intensities of the PMS with a particle size of 110 nm and a volume concentration of 25% measured with the Blue and IR tower, respectively. The color-coding of the curves indicates the time at which they were recorded, from red (first measurement, t = 0 s) to purple (last measurement, t = 60 s). Every curve represents an individual measurement.

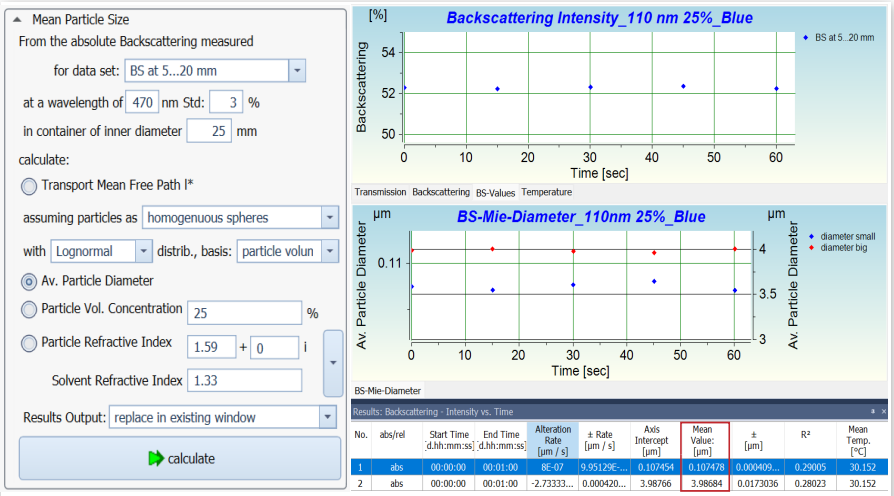


Fig. 5: Evaluation of the mean values of backscattering intensity over time and mean particle size of 110 nm 25% PMS using the Blue tower

With the 'Values'-method in the MSC software, the mean values of the backscattering intensity at a defined position range from 5 mm to 20 mm can be analysed utilising absolute backscattering intensities. Fig. 5 top and Fig. 6 top show that the backscattering intensity of PMS sample measured with the Blue and IR tower are 52.3% and 29.1%, respectively. This is consistent with the conclusion from a previous note[3] that reported higher backscattering values with the Blue tower compared to the IR tower for liquid dispersions containing nano particles.

Based on the backscattering intensity values, the mean particle size of the PMS can be easily obtained within the software. As discussed in the Technique and Method part, two values of particle diameter are obtained in Fig. 5 bottom and Fig. 6 bottom, respectively. The calculated particle diameters are around 107 nm and 3.99 µm when using the backscattering intensity measured with the Blue tower, while the IR tower furnishes particle diameters of around 116 nm and 17.27 µm. Combining these results, the mean particle size can be confirmed to be between 107 nm and 116 nm. It is consistent with the data information described on the package.

Furthermore, this technique can also be applied to bigger particles in the micrometer range. Fig. 7 and Fig. 8 show the results for the PMSs with a particle size of 1.2 µm. Based on the backscattering intensity measured with the Blue tower and the IR tower, diameters around 152 nm and 1.17 µm as well as 304 nm and 1.24 µm were found. These results suggest that the mean particle size is between 1.17 µm

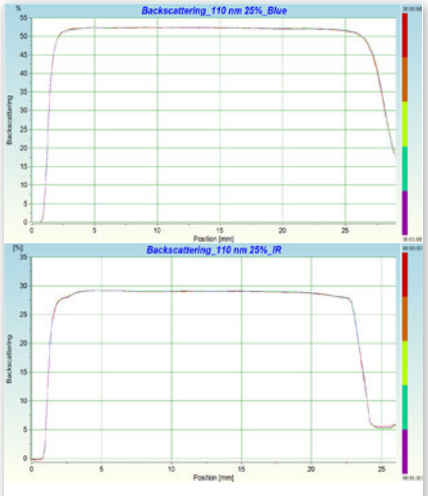


Fig. 4: Backscattering diagrams of 110 nm 25% PMS from the Blue tower and IR tower, respectively

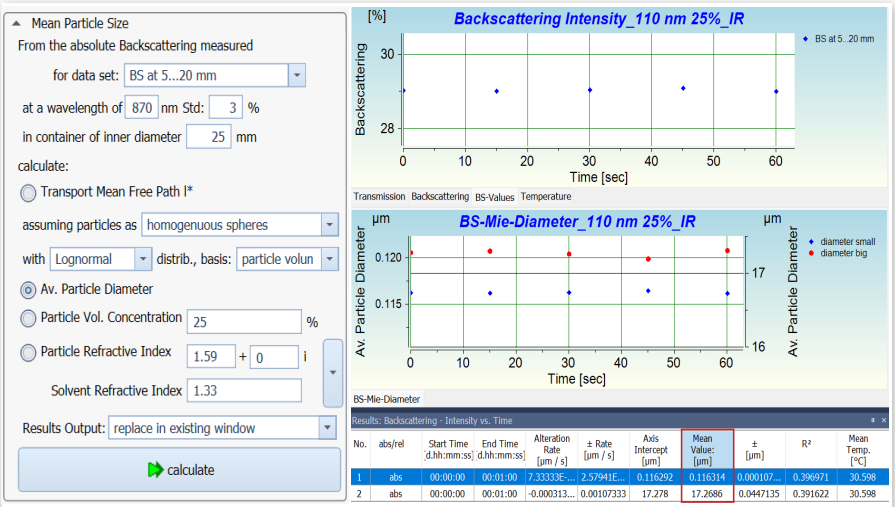


Fig. 6: Evaluation of the mean values of backscattering intensity over time and mean particle size of 110 nm 25% PMS using the IR tower

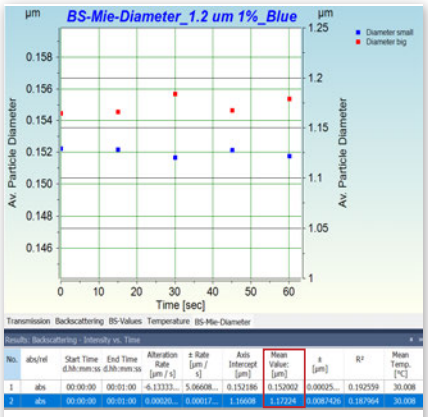


Fig. 7: Evaluation of the mean particle size of 1.2 µm 1% PMS using the Blue tower

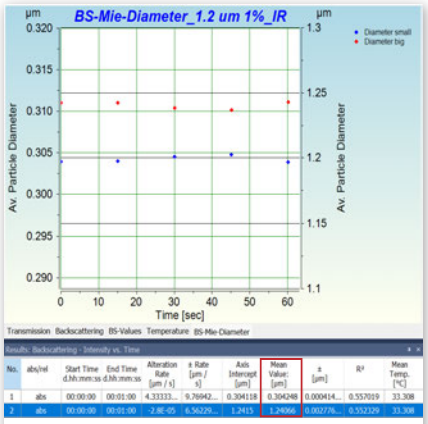


Fig. 8: Evaluation of the mean particle size of 1.2 µm 1% PMS using the IR tower

and 1.24 µm, which is in good consistency with the data information described on the package.

It is noteworthy that the volume concentration and refractive index of solvent and particles have a big influence on the mean particle size evaluation.

Summary

It can be concluded that the MS 20 MultiScan dispersion stability analysis system combining Blue and IR towers can help to find the right mean particle size. The results described above underline the excellent applicability of MS 20 not only for the analysis of dispersion stability, but also to calculate the mean particle size based on Mie theory with high validity.

The new ScanTower with Blue-LEDs broadens the possibilities of MultiScan MS 20 to study the stability and aging of liquid dispersions. Working together with the IR tower, it will be especially useful to those who work in research and industry fields, such as cosmetics, food, chemistry, and pharmaceuticals.

References

[1] https://www.dataphysics-instruments.com/products/ms/
[2] Zhou H., Li L. *Experimental research on size distribution of suspended particles in water based on Mie scattering theory.* IOP Conf. Ser.: Earth Environ. Sci. 2021, 769, 042063. DOI:10.1088/1755-1315/769/4/042063
[3] https://www.dataphysics-instruments.com/application/notes/

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