Advances in Particle Size Analysis by Laser Obscuration Time

Combined technologies for particle size, shape and concentration measurement

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1. The Laser Obscuration Time method Introduction

The Laser Obscuration Time method is based on the interaction of the rotating laser spot with a particle which creates the " Obscuration Time" pulse. This is a single particle interaction.
Analysis of the **pulse width** (duration), yields the **SIZE** of the particle.

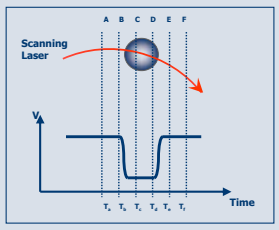


Figure 1. - Obscuration Time pulse

The Obscuration Time (t) together with the known rotation velocity of the laser beam (v) makes it possible to calculate the particle diameter (D), so that:

$$D = v \cdot t$$

In relation to the high speed of the rotating laser, the particles are nearly stationary. This eliminates possible errors due to particle movement.

2. Interaction pulses types

There are few parameters affecting the shape of the particle's interaction pulse, all considered by the TOT method:

2.1. Out of focus particle
The laser beam is focused to a small spot size and is expanding gradually , in both directions along the beam: in front of and in back of the focused spot.
When a particle is scanned away from the focused spot, the effect on the interaction pulse will be:
- Pulse edges will be less steep, with broader derivatives because of the expanded laser spot
- Pulse amplitude may be smaller, as particle may be smaller than the expanded laser spot and obscuration is not complete.

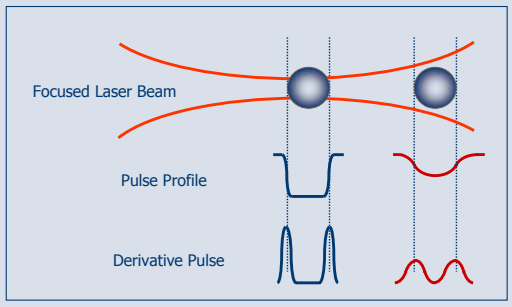


Figure 2. - Out of focus rejection

2.2 Out of center particle

The laser spot rotates and scans particles flowing through it. When a spherical particle is scanned along its diameter, the size analysis is correct. When the particle is scanned far away from its diameter, size analysis may be deviated to smaller value.
When a particle is scanned away from its diameter, the effect on the interaction pulse will be:
- Pulse edges will be less steep with a narrow derivative signal , as the particle edges are more slanted along a chord rather than a diameter.
- Pulse amplitude may be smaller, as the laser spot may not be completely obscured by the particle, while crossing it at its very edge.

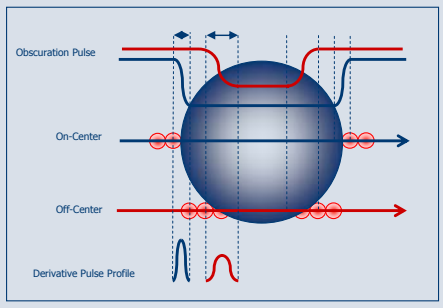


Figure 3. - Out of center situations

2.3 Non opaque particle

In general with TOT method, the size analysis is independent of the index of refraction of the particles. When an opaque particle is scanned, total laser spot obscuration occurs and the amplitude of the interaction pulse width is maximal.
When a particle is not totally opaque, the effect on the interaction pulse will be:
- Pulse amplitude may be smaller, as some light reaches the detector even when the laser spot is in position to be completely obscured by the particle.

3. Independent Measurement

The Laser Obscuration Time method for size measurement is independent of the sample's refractive index, as long as there are resolvable interaction pulses.
As the refractive index spectrum of the various samples is wide, the Laser Obscuration Time method simply measure the distance between the particle's boundaries:

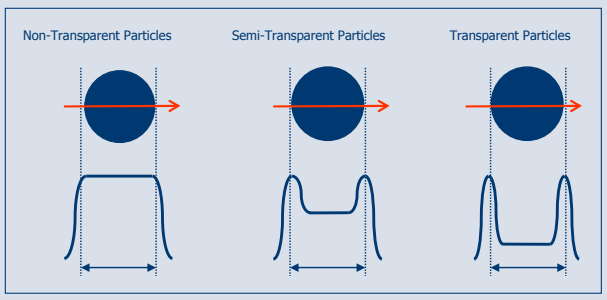


Figure 4. – Independence of optical properties

4. Dynamic Image Analysis

Not all problems in particle sizing can be solved by assuming a spherical shape. Sometimes the information obtained from imaging is necessary. Dynamic Visualization shows the particles in the measuring zone on the monitor. Two dimensional analysis of video images enabling the determination of different shape parameters, such as Feret Diameters, Shape Factor and Aspect Ratio calculation, etc. In addition discrimination of particles by using strategic Shape Filter options is available.

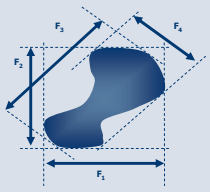
What are the sizes of these particles?

Every particle size analyzer yields different sizes to non-spherical particles
Particles like fibers, rods, etc., can not be defined by one parameter

Shape Analysis Size = average Feret diameter

$$\frac{F1 + F2 + F3 + F4 \ldots F36}{36}$$

Where for a sphere size it would be diameter.

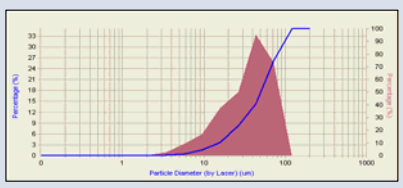


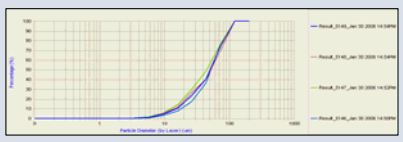
S.F. = 1 S.F. < 0.7

Spherical particle agglomerates can be discriminated by Shape Factor

5. Results

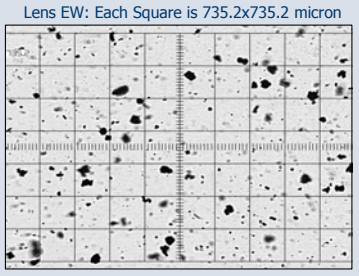
Variety of output presentations are available: differential histograms, cumulative graphs, tables, statistical results, graph on graph comparisons and real images of the measured particles.



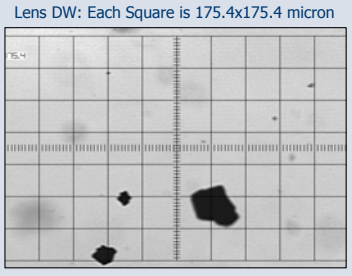


Undersize(%)	Average Ferets(µ)	Oversize(%)
5.00	88.39	95.00
10.00	107.84	90.00
15.00	124.03	85.00
20.00	137.82	80.00
25.00	148.86	75.00
30.00	158.84	70.00
35.00	167.79	65.00
40.00	177.30	60.00
45.00	186.14	55.00
50.00	193.95	50.00
55.00	202.05	45.00
60.00	210.29	40.00
65.00	219.60	35.00
70.00	228.58	30.00
75.00	237.15	25.00
80.00	247.89	20.00
85.00	259.35	15.00
90.00	278.71	10.00
95.00	463.69	5.00

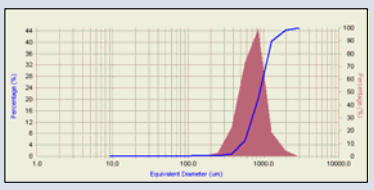
Lens EW: Each Square is 735.2x735.2 micron



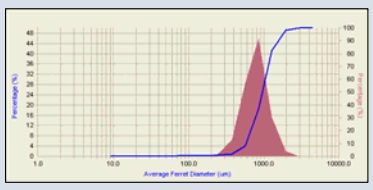
Lens DW: Each Square is 175.4x175.4 micron



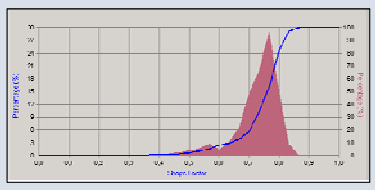
Equivalent Diameter



Average Fetet Diameter



Shape Factor



6. The EyeTech System

The EyeTech combines two methods of analysis:

Laser channel: particle size measurement by means of Laser Obscuration Time.

A He-Ne laser beam (A), focused down to 1.2 um spot, performs circular scanning by a rotating wedge prism (B) of the sample measurement volume (G). As the particles (moving or stationery) within the sample volume are individually bisected by the laser spot, interaction signals are generated. These signals are then detected by a PIN photodiode (D). Since the beam rotates at a constant speed, the duration of interaction provides direct measurement of each particle's size. The interaction signals are collected by a dedicated data acquisition card and analyzed in 600 discrete size intervals. Pulse analysis algorithms are employed to reject out-of-focus and off-center interactions.

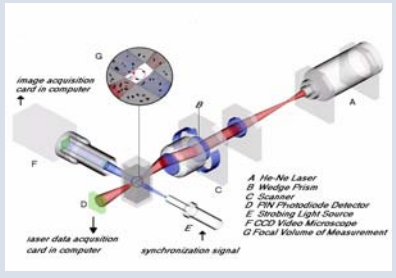


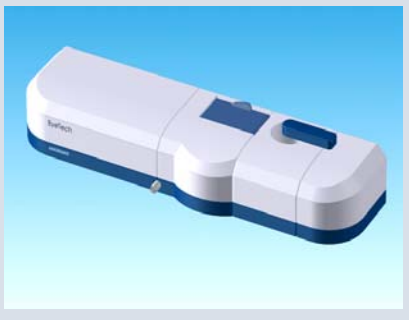
Figure 5. – EyeTech Laser and Video channels

Video channel: shape characterization by acquiring images of moving particles and analyzing them with Image Analysis software

The shape analysis channel uses a CCD video camera microscope (F) to provide an optimal image for processing. Illumination is provided by a synchronized strobe light (E). Acquired images are passed to a frame grabber card for analysis and then displayed on a monitor for viewing.

7. Conclusion

- Direct measurement of particle size: measurement relates solely and directly to particle size, rather than to secondary properties from which size may be inferred. This eliminates inconsistencies due to sample refractive index, viscosity variations, Brownian motion and thermal convection.
- High resolution (0.2 um) and wide dynamic range (0.1-3600 um).
- Concentration measurement
- No assumption of spherical particles
- No calibration required
- Operation in liquid, gas or surface
- Applicable to broad concentration range
- No need for refractive index
- Answer to agglomeration and non-spherical particles
- Shape Analysis; Multiple parameters available



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