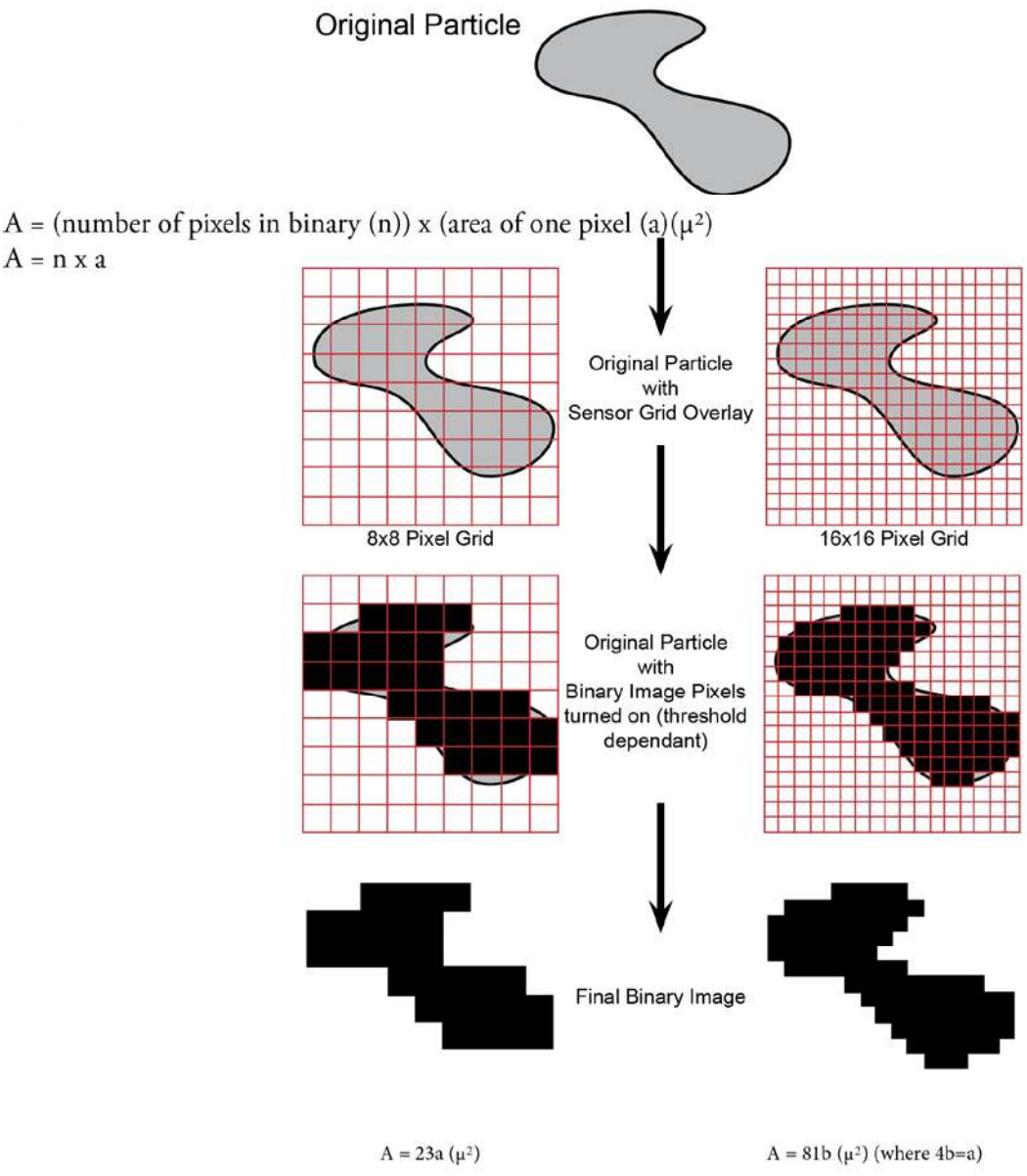
# Glossary of Particle Properties & Other Terms

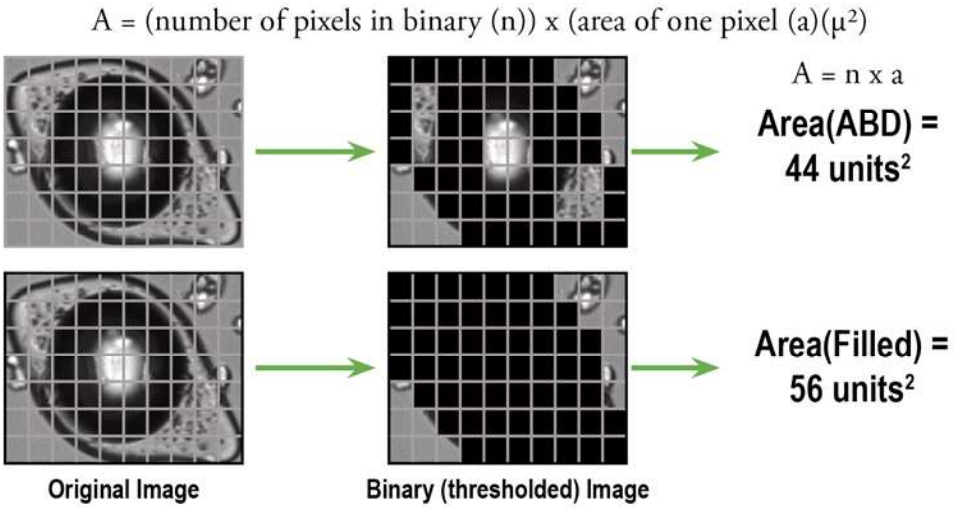
The following list of definitions applies to VisualSpreadsheet Version 3.4 particle property fields. Note that most of these definitions also apply to older versions of VisualSpreadsheet, including 3.0 and 2.0 software.

**Area:** Number of pixels in the threshold (binary) greyscale image converted to a measure of area by use of the calibration factor. (real >0) (Also see Appendix, Imaging Concepts - Thresholding)

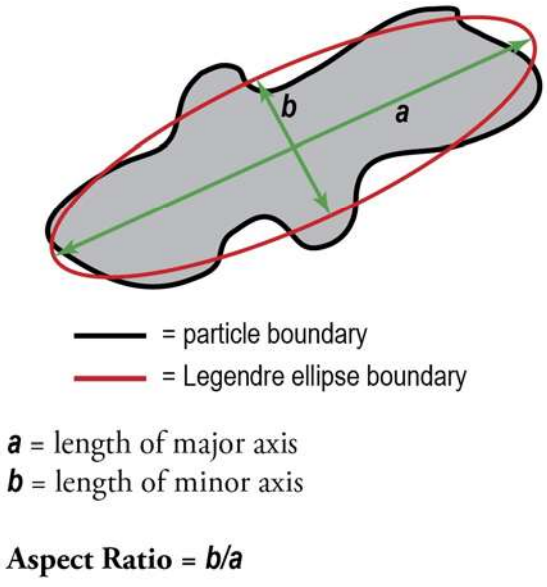


**Area (ABD):** Number of pixels in the thresholded (binary) greyscale image converted to a measure of area by use of the calibration factor. (real > 0) (see diagram below)

**Area (Filled):** The area represented by the particle edge and all the pixels inside the edge. (real >0)
In the case of an opaque particle Area (Filled) = ABD. However, if parts of the particle are transparent, and therefore do not threshold as "particle", then Area (Filled) > ABD, as shown in the example below:




**Aspect Ratio:** The ratio of the lengths of the axes of the Legendre ellipse of inertia of the particle. The Legendre ellipse of inertia is an ellipse with its center at the particle's centroid, and with the same geometrical moments, up to second order, as the original particle area. A circle has the value 1.0 as does a square. Values near zero are for particles that are long and thin. (real [0, 1])
Reference: ISO 9276-6:2008




**Average Blue:** Average pixel value of the blue color plane. (real [0, 255]; 255 is intense blue)
**Average Green:** Average pixel value of the green color plane. (real [0, 255]; 255 is intense green)
**Average Red:** Average pixel value of the red color plane. (real [0, 255]; 255 is intense red)

**Calibration Factor:** The conversion factor from pixels to microns (units are microns per pixel). (real, fixed for each instrument)

**Calibration Image:** The number of the calibration image that was used in processing the particle. (integer > 0)

**Camera:** The camera number.

**Capture X:** The leftmost X coordinate in pixels of the particle in the original image. (integer in range of the acceptable region)

**Capture Y:** The top Y coordinate in pixels of the particle in the original image. (integer in range of the acceptable region)

**Ch1 Area:** Area of fluorescence peak of PMT #1 measured over the width (Ch1 Width). (real ≥ 0)

**Ch1 Peak:** Peak fluorescence value read from PMT #1. (real ≥ 0)

**Ch1 Width:** Sample width of PMT #1 above the threshold value. (real ≥ 0)

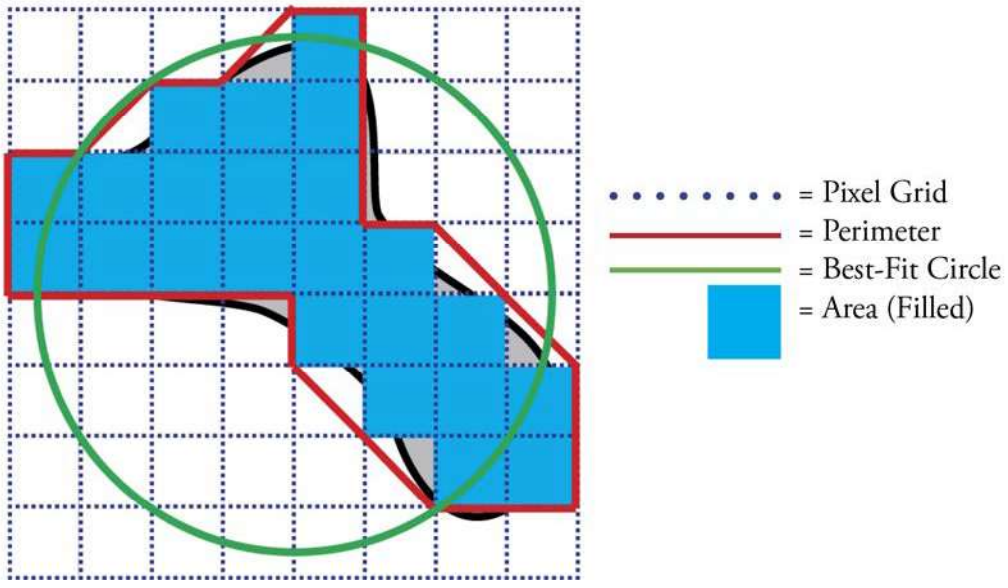
**Ch2 Area:** Area of fluorescence peak of PMT #2 measured over the width (Ch2 Width). (real ≥ 0)

**Ch2 Peak:** Peak fluorescence value read from PMT #2. (real ≥ 0)

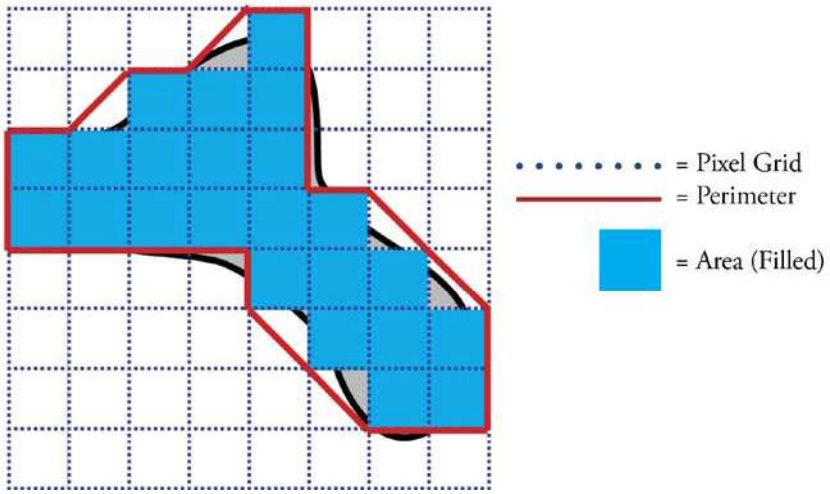
**Ch2 Width:** Sample width of PMT #2 above the threshold value. (real ≥ 0)

**Ch2/Ch1 Ratio:** Ch2 Peak / Ch1 Peak. (real ≥ 0)

**Circle Fit:** Deviation of the particle edge from a best-fit circle, normalized to the range [0,1] where a perfect fit has a value of 1. (real [0, 1]; 1 is the value for a perfect circle; values near zero are for particles that are not at all circular)



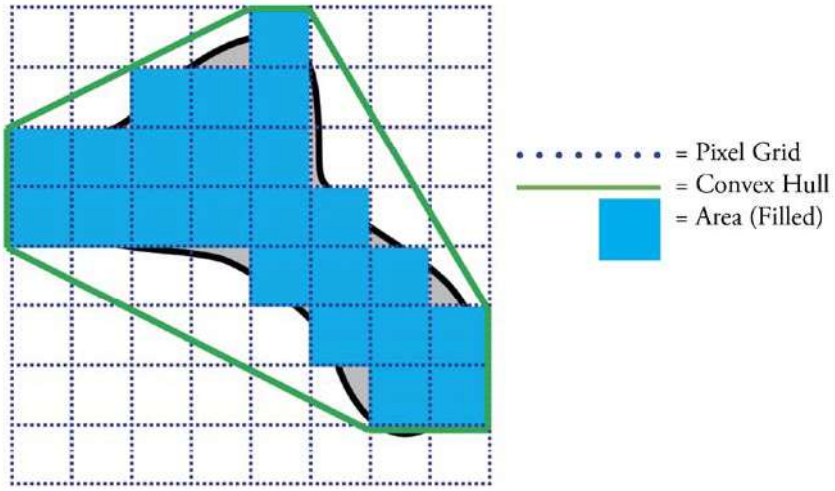
**Circularity:** A shape parameter computed from the perimeter and the (filled) area. A circle has a value of 1.0. Circularity is the inverse of Compactness. Formula: (4 x π x Area) / Perimeter². (real [0,1]) = Pixel Grid = Perimeter = Best-Fit Circle = Area (Filled)




**Circularity (Hu):** An alternative measure of circularity that often provides a better indication of the circular shape of a particle than does Circularity, especially if the particle is very small or its edge has defects. A circle has a value of 1.0. (real [0, 1]) (Ref: "A Hu moment invariant as a shape circularity measure" by Zunic, Hirota, and Rosin, Pattern Recognition 43 (2010) pp 47-57)

**Compactness:** A shape parameter derived from the perimeter and the (filled) area. The more convoluted the shape, the greater the value. A circle has a value of 1.0. Compactness is the inverse of Circularity. Formula: Perimeter² / (4 x π x Area). (real ≥ 1)

**Convexity:** A shape parameter that is computed as the ratio of filled area to the area of the convex hull of the particle. This property is sometimes called Solidity. A circle has a value of 1.0. (real [0, 1]) (A simple way of thinking of the convex hull is to imagine taking a rubber band and stretching it around the filled area)



**Date:** The date the image was captured. (text string of the form mm/dd/year)

**Diameter (ABD) (Area Based Diameter):** The diameter based on a circle with an area that is equal to the ABD Area. (real > 0) (see "**Area**")

**Diameter (ESD) (Equivalent Spherical Diameter):** The Mean value of 36 feret measurements. (real > 0) (see "**Feret Measurement**")

**D[4,3] (ABD) and D[4,3] (ESD):** These values (the volume moment mean of the particle) are the mean diameter computed by weighting the ABD or ESD diameter of each particle by the ABD or ESD volume of the particle. Because of the weights, the particles with large volume influence the mean more than the particles with small volume.

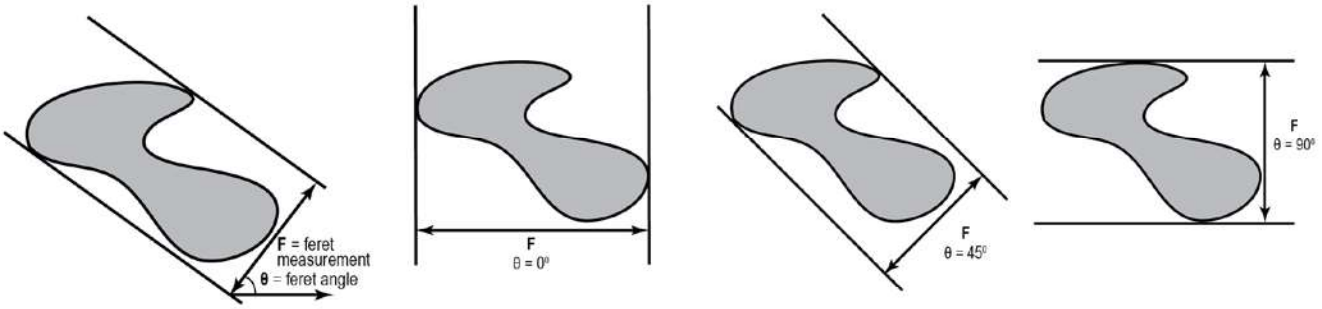
**Edge Gradient:** Average intensity of the pixels making up the outside border of a particle after a Sobel Edge Detect convolution filter has been applied to the raw camera image. (real [0, 255]) Example:


**Elongation:** The inverse of Geodesic Aspect Ratio. (real ≥ 1; 1 is the value for a circle or square; larger values are for elongated particles)

**Feret Angle Max:** Angle of the largest feret measurement. (real [-90, +90])

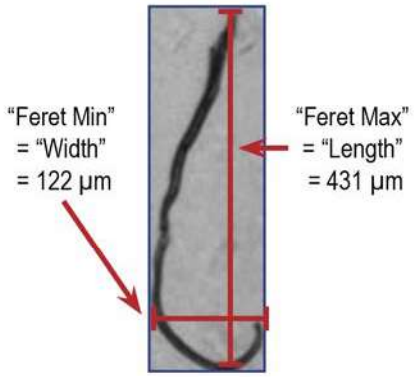
**Feret Angle Min:** Angle of the smallest feret measurement. (real [-90, +90])

**Feret Measurement:** The perpendicular distance between parallel tangents touching opposite sides of the particle. VisualSpreadsheet makes 36 measurements for each particle, one each 5 degrees between -90 degrees and +90 degrees. These measurements are used to calculate the particle properties Diameter (ESD), Length and Width. Examples:

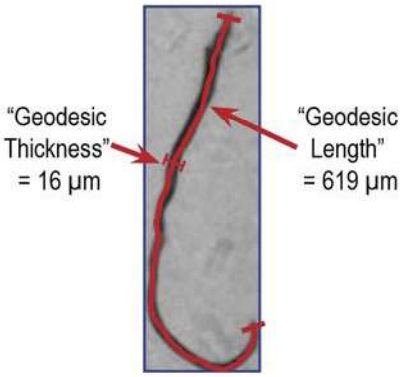


**Fiber Curl:** A shape parameter computed from Geodesic Length and Length. Also known as Curl Index. Formula: (Geodesic Length / Length) – 1. (real ≥ 0) (see Fiber Measurements)

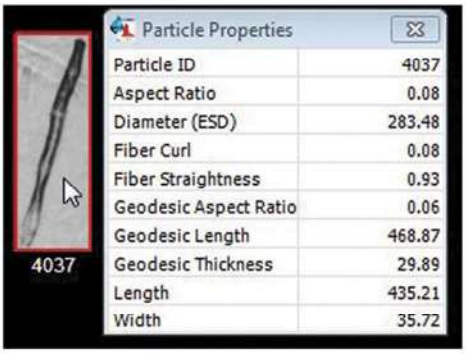
**Fiber Measurements:** The length and width of fibers can be measured two different ways, via "fereting" (see Feret Measurements) or using Geodesics. For non-straight fibers, the preferable method is using Geodesics, as can be seen in the example below. Additionally, using both Feret and Geodesic-based measurement leads to additional useful descriptors such as Fiber Curl and Fiber Straightness.

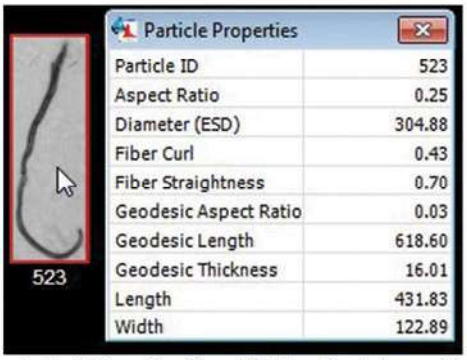



Feret-Based "length" and "width"




Geodesic-Based "length" and "width"




Note the differences seen in the measurements, particularly "Fiber Curl" and "Fiber Straightness" between these two fibers having nearly the same ESD.

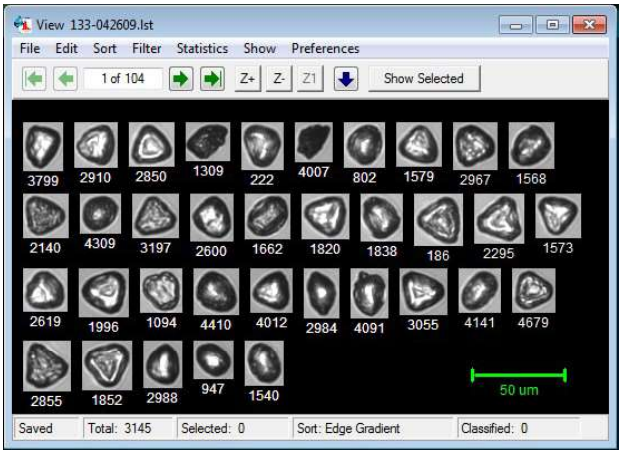
**Fiber Straightness:** A shape parameter computed from Geodesic Length and Length. Formula: Length / Geodesic Length. (real ≥ 0) (see Fiber Measurements)

**Filter Score:** The statistical filter score. (real ≥ 0)

**Geodesic Aspect Ratio:** The ratio of Geodesic Thickness to Geodesic Length. Elongation is the inverse of this ratio. (real [0, 1])

**Geodesic Length and Geodesic Thickness:** Values obtained by modeling the particle as a rectangle and computing length and thickness by solving the equations:
Area = Geodesic Length x Geodesic Thickness
Perimeter = 2 x (Geodesic Length + Geodesic Thickness)
where Area is filled area and Perimeter is the length of the particle edge not including the lengths of edges of holes in the particle. (real > 0) (see Fiber Measurements)

**Holes:** "Holes" may occur in binary particle images where particles have some degree of transparency, due to the center of the particle being "lighter" and closer to the background gray scale level. This varies greatly depending on the thresholding settings made during acquisition. However, it is important to be cognizant of "holes" in the binary images, as these do affect some of the particle measurements (as noted in the descriptions contained in this appendix). The images below demonstrate how holes appear in the binary images:



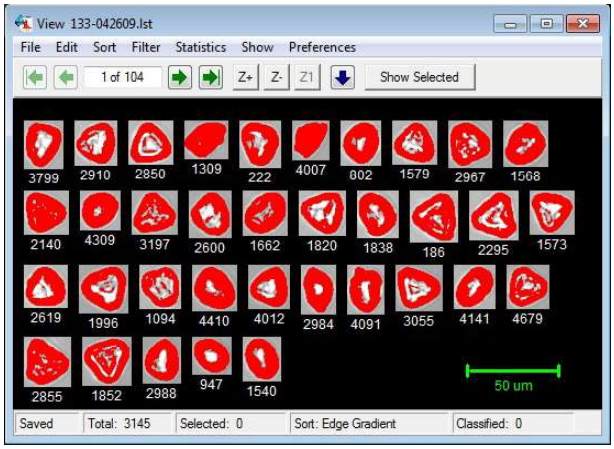




**Image File:** The collage image filename that contains this particle. (text string of the form filename_nnnnnn.tif)

**Image Height:** The image height in pixels of the particle in the saved collage image. (integer > 0)

**Image Width:** The image width in pixels of the particle in the saved collage image. (integer > 0)

**Image X:** The left most X coordinate in pixels of the particle image in the saved collage image. (integer ≥ 0)

**Image Y:** The top Y coordinate in pixels of the particle in the saved collage image. (integer ≥ 0)

**Intensity:** The average grayscale value of the pixels making up a particle (grayscale sum / number of pixels making up the particle). (real [0, 255]; 255 is most intense)

**Length:** The maximum value of 36 feret measurements. (real > 0) (see Feret Measurement)

**Particle ID:** The particle identification number.

**PPC (Particles Per Chain):** The number of particles that were grouped into one particle based on the nearest neighbor distance. (integer > 1; almost always 1 if nearest neighbor distance is 0)

**Perimeter:** The length of the particle edge not including the lengths of edges of holes in the particle. (real > 0) (see Diagram in Circularity)

**Ratio Blue/Green:** Average Blue / Average Green (when using color camera only). (real ≥ 0)

**Ratio Red/Blue:** Average Red / Average Blue (when using color camera only). (real ≥ 0)

**Ratio Red/Green:** Average Red / Average Green (when using color camera only). (real ≥ 0)

**Roughness:** A measure of the unevenness or irregularity of a particle's surface-the ratio of perimeter to convex perimeter. (real ≥ 1; 1 is the value for a filled shape with convex perimeter; larger values are for particles that have interior holes and/or a non-convex perimeter)


**Scatter Area:** Area of the peak of the scatter detector measured over the width. (real ≥ 0)

**Scatter Peak:** Peak value read from the scatter detector. (real ≥ 0)

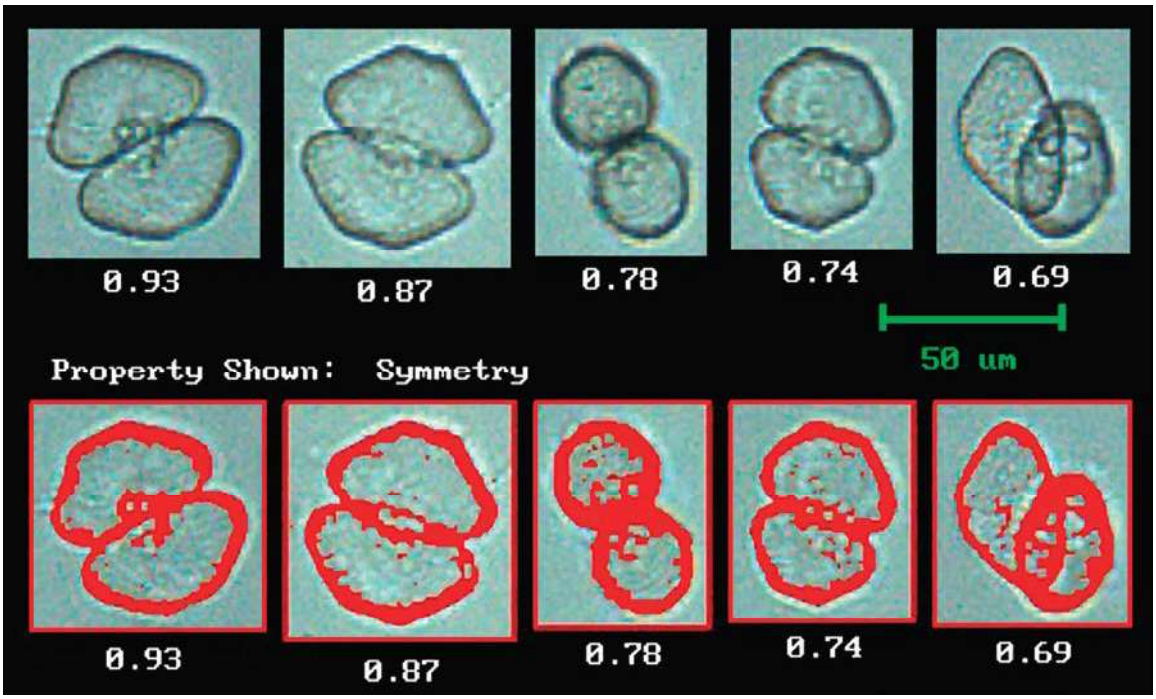
**Scatter Width:** Sample width of scatter detector values above the scatter threshold. (real ≥ 0)

**Sigma Intensity:** Standard deviation of grayscale values. (real ≥ 0)

**Source Image:** The camera image number or raw file image number where the particle was captured. (integer > 0)

**Sum Intensity:** Sum of grayscale pixel values. (real > 0)

**Symmetry:** A measure of the symmetry of the particle about its center. If a particle is symmetric about the center then the value of Symmetry is 1.0. Typically used to locate 'broken' or partial particles. (real [0, 1])




**Time:** The time that the image was captured.

**Timestamp:** The time the image was captured in milliseconds.

**Transparency:** 1 – (ABD Diameter / ESD Diameter). (real [0, 1]; 0 is the value for a filled circle; values near 1 are for an elongated or irregular shape or a shape that has many interior holes)

**Volume (ABD):** Sphere volume calculated from ABD Diameter. (real > 0)

**Volume (ESD):** Sphere volume calculated from ESD Diameter. (real > 0)

**Width:** The minimum value of 36 feret measurements. (real > 0) (see Feret Measurement)