LASER DIFFRACTION IN MINING AND GEOLOGY

UNLOCKING VALUE ACROSS EXPLORATION, PROCESSING, ENVIRONMENTAL STEWARDSHIP, AND CONSTRUCTION MATERIALS

CONTEXT

The mining and geology industries are pillars of North American economic activity, shaping landscapes, driving technological progress, and supplying vital raw materials. In these fields, understanding the size distribution of particles, whether in soils, ores, aggregates, or sediments, is crucial for making informed decisions at every stage, from exploration to environmental monitoring. The SYNC combines Laser Diffraction and Dynamic Image Analysis (DIA) for powerful particle characterization tool.

ADVANTAGES OF LASER DIFFRACTION

Particle size has a direct impact on the physical and chemical properties of geological and mineral samples. And the measurement and control of particle size is essential to almost every part of the mining value chain. There are several benefits to using laser diffraction for these purposes.

- **Speed and Throughput**: Typical analysis is completed in minutes, with automated measurement and cleaning sequences.

- **Wide Dynamic Range**: Suitable for a vast array of materials, from sub-micron clays to millimeter sands.
- **Versatility**: Accommodates wet (FLOWSYNC) or dry (TURBOSYNC) samples, various volumes, and offers multiple options for sample preparation.
- **Accuracy and Reproducibility**: Performance that surpasses ISO 13320 standards.

KEY APPLICATION AREAS FOR MINING AND GEOLOGY

The following sections highlight how various areas benefit from this technology, using real-world scenarios and practical examples.

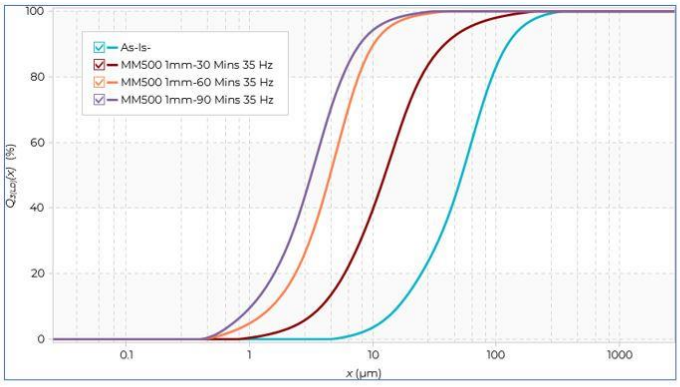
Mineral Exploration and Resource Characterization

During mineral exploration, geologists must accurately assess the properties of soils and rock formations to identify areas of interest. Particle size distributions provide critical clues about past geological processes, such as erosion, sediment transport, and mineralization events.

Analyzing the surrounding geology can help delineate pay zones, or optimize the placement of drill holes. In hard rock mining, grain size data assist in mapping alteration halos and guiding selective sampling, significantly increasing the precision of resource estimates while reducing exploration risk.

Ore Processing and Mill Optimization

Once ore is brought to the surface, efficient processing is critical. Size reduction accounts for a large portion of operational costs and tremendous energy use. The downstream efforts are mostly focused on the liberation of valuable minerals, processes that have idealized particle sizes for efficiency.
By integrating laser diffraction analyzers into processing plants, many mines have shifted away from intermittent, manual processes like sieving and sedimentation. Rapid and automatable instruments like the SYNC helps make informed decisions on mill adjustments. The outcome is increased throughput, reduced costs, and enhanced metallurgical recovery. ***Figure 1*** shows particle size data from a milling experiment.



Milling experiment: Feldspar (Alumino Silicate)
Wet grinding in Retsch MM500 mixer mill, ZrO_2 jar, 30 Hz
Blue: As-Is Sample
Red: 30 mins grinding
Orange: 60 mins grinding
Purple: 90 mins grinding

Percentile	As-Is	30 mins	60 mins	90 mins
D10	16.25 µm	3.85 µm	1.53 µm	1.04 µm
D50	53.12 µm	12.59 µm	4.53 µm	3.18 µm
D90	124.9 µm	38.7 µm	10.25 µm	7.92 µm

Figure 1*:Detailed particle size data from a milling experiment, including graphical and tabular distribution percentiles. This information helps assess grinding performance, optimize mill settings.*

Flotation and Leaching Control

Downstream beneficiation processes such as flotation and leaching depend intimately on particle size. For instance, the flotation efficiency drops if feed particles are too fine or too coarse, affecting both product quality and yield. Understanding size distributions is constant feedback to improve the flotation control to maximize recovery and minimize reagent use. Similarly, in leaching operations, maintaining a uniform particle size distribution ensures that lixiviant solutions permeate effectively without reabsorption. Again, the consideration of particle size is key to maximizing metals extraction. ***Figure 2*** shows an example data created by the STABINO ZETA, which can supplement beneficiation.

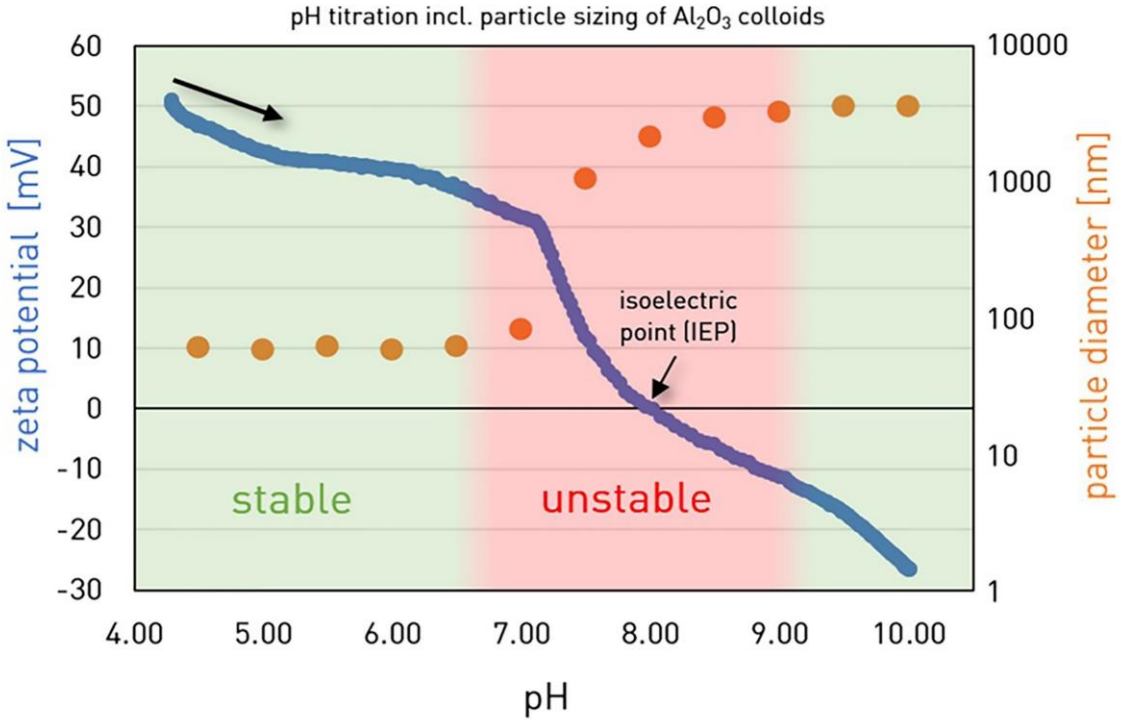


Figure 2: *Streaming zeta potential for an alumina suspension undergoing a base (NaOH) titration.*

This information reveals the extent of dispersion or agglomeration for the slurry during beneficiation. In addition to particle size analysis, measuring colloidal stability can improve overall beneficiation.

Environmental Monitoring and Regulatory Compliance

North American mines are subject to strict environmental regulations concerning water discharge, dust emissions, and tailings management. For example, measuring the particle size distribution of tailings pond effluents helps ensure compliance with standards set by institutions like the Environmental Protection Agency (EPA) in the United States and Environment and Climate Change Canada (ECCC). For coal mining regions, monitoring of sediment-laden runoff can enable prompt corrective action and better cooperation with regulatory authorities. For dust control, such as in open-pit mines or aggregate quarries, knowing the size of airborne particles supports effective mitigation strategies to protect operations and nearby residents.

Construction Aggregates and Geotechnical Applications – Utilizing both Laser Diffraction and Dynamic Image Analysis

The construction sector relies heavily on aggregates, sand, gravel, and crushed stone, whose performance is dictated by particle size distribution. Concrete strength, road durability, and the stability of embankments or foundations all require precise gradation.

Laser diffraction replaces time-consuming traditional sieving, offering faster, more detailed particle size profiles. Aggregate producers use this technology to ensure their products meet the rigorous standards of state departments of transportation and private clients alike. In large infrastructure projects, such as highway or dam construction, rapid feedback on gradation translates into better material utilization,

reduced waste, and safer, longer-lasting structures. ***Figure 3*** is an example of particle size distribution data for a multi-modal calcium oxide after calcination.

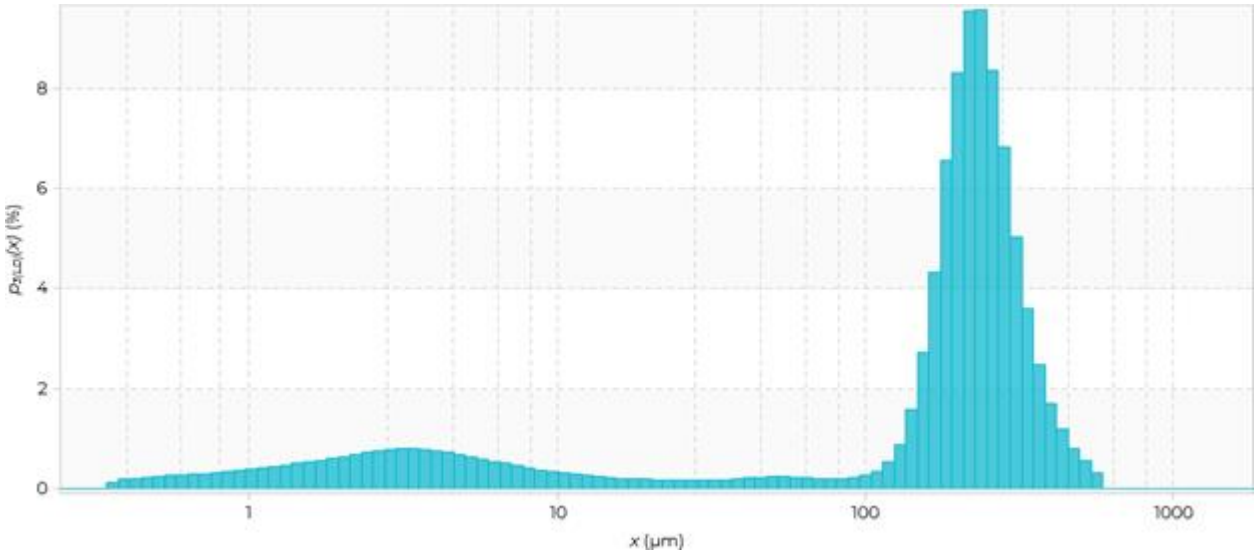


Figure 3: *Representative particle size distribution for a coarse calcium oxide sample after high-temperature calcination*

The profile effectively quantifies gradation data that enables process engineers and quality assurance teams. In a scenario where this product is added to cement, this has a significant impact on hydration, expansion, and finished strength.

Particle shape analysis can be performed simultaneously with size measurement using the SYNC instrument, all within a single, integrated module and software platform. This combined data provides immediate, actionable insight into material behaviour during processing and in end-use applications. Critical performance factors such as flowability, separation efficiency, agglomeration potential, and final product strength are all influenced by particle shape. For instance, spherical particles tend to settle more quickly than flat or elongated particles, while needle-like shapes may incorrectly pass through screens, reducing separation accuracy. ***Figure 4*** illustrates real-time particle imaging captured during the same laser diffraction measurement.

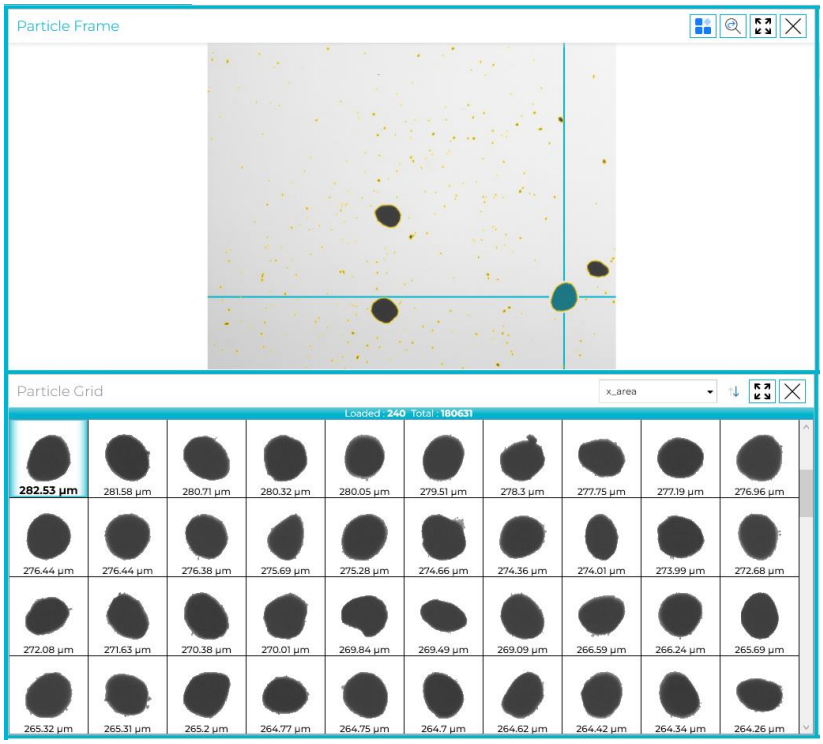


Figure 4*: example images collected by the SYNC*

The Particle Viewer workspace allows users to search, sort, and filter dynamic image analysis data. The SYNC operates laser diffraction and dynamic image analysis simultaneously, with a singular sample, flow path, and software.

Broad Particle Size Distribution, SEDIMENTS Software Feature

One of the issues in mining and geological samples is that they can often have a very wide particle size distribution ranging from below a micron to many millimeters or centimeters. In many cases, like clays or river sediments, it is very difficult to provide detailed data on both the small fractions and the larger fractions using laser diffraction alone. Laser diffraction measure the angular scatter of light depending on the size of the scattering particle. The larger the particle, the smaller the angle of scatter. As particles get larger, it becomes more and more difficult to detect changes in angular scatter. As such, Laser Diffraction is optimized for smaller particles as detection is easier. Conversely, as particles get larger, Dynamic Image Analysis is better at measuring larger particles accurately. The combination of Laser Diffraction and Dynamic Image Analysis SYNC instrument gives the best of both techniques. However, if samples contain a significant fraction of particles above the range of 5000 microns, even the SYNC cannot cover all eventualities. ***Figure 5*** shows the solution to the measurement range conditions, by using the **SEDIMENTS** option.

Figure 5*: Example of the sediment analysis data sheet*

This features allows the combination of particle size data from Microtrac laser diffraction and sieve measurements.

This allows the user to use a separate measuring technique, usually sieving, to separate the fractions down to about 60 Microns.
The sub 60 Micron fraction is then measured using laser diffraction to give detailed data on the material down to the sub- micron range. By then entering the Sieve fractions in the SEDIMENTS worksheet, the user is provided with a full particle size distribution for the entire sample like **Figure 6**.

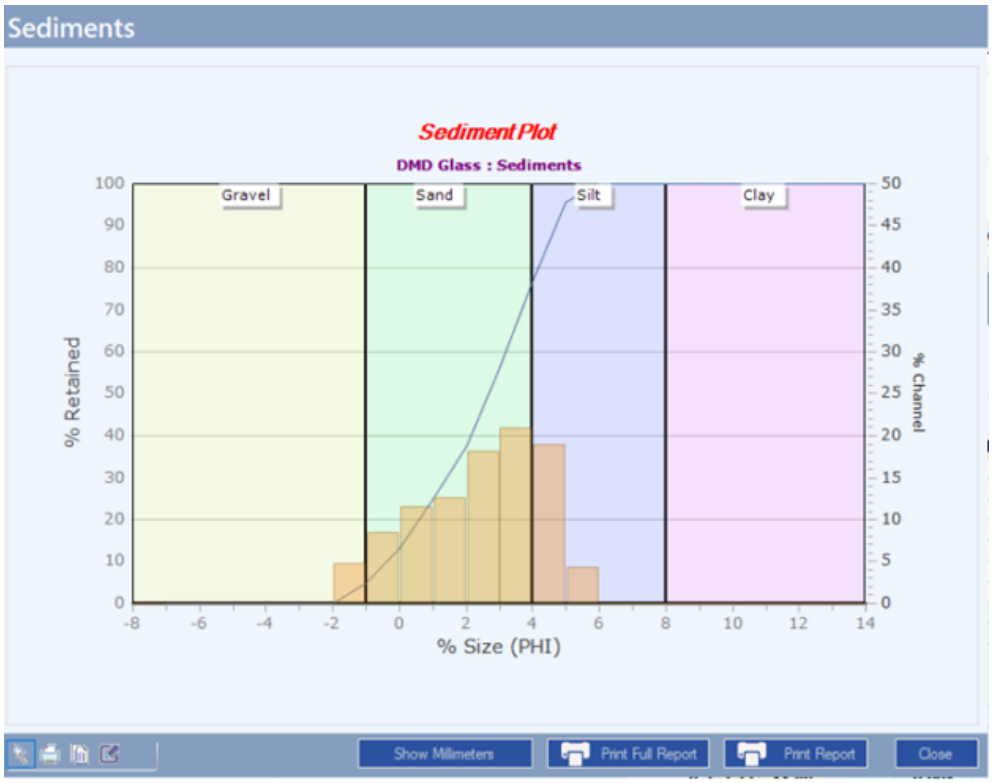


***Figure 6**: Sediment plot derived from two particle size techniques.*

Multiple display options include the Wentworth sediment scale, Phi logarithmic transformation, or ISO 14688-1 classifications.

CONCLUSION

Laser diffraction particle size analysis offers unparalleled speed, accuracy, and operational insight for mining and geology applications across North America. Whether accelerating exploration, optimizing processing, supporting compliance, or improving construction material quality, this technology equips industry professionals with the tools needed for a competitive, responsible, and sustainable future. As resource demands and regulatory expectations grow, the adoption of laser diffraction stands as a strategic investment that delivers efficiency, quality, and peace of mind across every stage of the mining and geology value chain.

More about the SYNC:
https://www.microtrac.com/products/particle-size-shape-analysis/laser-diffraction/sync/

References

- Life cycle assessment for sustainable mining. (2021). In *Elsevier* eBooks.
- https://doi.org/10.1016/c2020-0-01670-1