Total Solutions in Particle Characterization

APPLICATION NOTE

Understanding Diode and Other Lasers Used in Particle Size Instruments

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Application Note

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Particle Size Measuring Instrumentation

Throughout the history of laser particle size measurement many light sources have been used to act as source of incident light on particles. The most popular has been lasers. In the early 1970's Microtrac used Helium-Neon gas lasers as a source of a collimated, coherent light which provided a near single wavelength and is necessary in light scattering particle size measurements. Advancements in electronics lead to development of semi-conductor lasers popularly known as laser diodes. Thus, in the mid-1980s, Microtrac initiated use of these laser types in order to supply customers with long life stability and application, thus reducing service requirements and maintenance costs. Without question, Microtrac has shown these devices to have extremely high reliability and stability. Their use was adopted in 1990 with the advent of the Ultrafine Particle Size analyzer (UPA) and extended to the modern Nanotrac and Ultra models employing dynamic light scattering measurement of nanosize particles. This note addresses questions that often arise when types of lasers are considered by customers and lay particle size personnel. It also attempts to address how sound optical design principles and technical knowledge addresses issues during instrument design.

What is the difference between a He-Ne gas laser and a diode laser? A gas laser utilizes electrical energy to excite a gas to such an extent that the electrons in the molecules achieve a high energy. When enough gas molecules are in this excited state, light is emitted as they return to a lower energy level. The energy is released as heat and several wavelengths of light. One wavelength predominates. The heat can cause intensity changes unless carefully controlled or cause a rise of internal instrument cabinet temperature. Temperature control of sample would be necessary.

Diode lasers use semi-conductor materials to produce the laser in much the same way but a gas is not used. The voltage required to cause *lasing* is much less and thus heat generation is not an issue to either the sample or electronics stability.

Diode lasers can be adjusted either manually or by on-board electronics. He-Ne gas lasers degrade over time and must then be discarded, Diode lasers have been proven for over 20 years to exhibit long life and long term stability.

Dispersion - What is it? Dispersion is an effect of a substance on light. This is easily observed by noting that a prism will separate normal white light into its components of the colors in a rainbow or the visible spectrum. Chandeliers exhibit high dispersion since the crystal separates light into its various wavelengths and colors as seen on the wall. In terms of a laser, it has very little meaning since lasers by design are nearly a single wavelength. As well, dispersion is a property of a material not of laser design. Often dispersion is confused with beam divergence.

Divergence – What is it? Divergence is defined as the increase in beam diameter with distance from the aperture. Gas laser beams can diverge as much as much as 1600 meters (1 mile) if directed at the moon from Earth. A semiconductor laser emits a beam which will exhibit similar or greater divergence; however, by selection of lens the beam divergence can be made as small as that from a gas laser. Lenses in Microtrac instruments including the probes of Nanotrac and Ultra use a specially selected lens to achieve a nearly non-divergent beam. Collimated beams of light are said to exhibit very small divergence. Note that due to diffraction effects, a perfectly collimated beam of light is impossible to produce by any means.

Coherence – What is it? Cohesion is a condition where waves are in phase (crests and valleys of waves are superimposed) in both time and space. Thus, the waves are emitted at the same time and stay together and exhibit very low beam divergence. Normal white light from a light bulb or flashlight is not coherent since: (1) the light will separate in a prism (2) has high divergence and (3) does not exhibit collimation.

Single mode fiber and multi-mode optical fibers – What is the difference? Optical fibers or waveguides are used to convey light over large distances while maintaining intensity. A single mode fiber allows the light waves to "stay together" better providing higher signal. This is important in Ultra where very small particles (scatter light much less well than larger particles) of the size 0.8nanometrs are desirably measured. At larger sizes above 30 – 50 nm a multimode fiber can be used since obtaining high scattered light signals is more easily accomplished.

Detector Devices – Why does Microtrac use a silicon detector in its Dynamic Light Scattering instrument like the Nanotrac? There are several ways to detect the light scattered by particles undergoing Brownian motion and diffusion, or diffraction. Microtrac instruments use only **silicon detectors**. Silicon detectors are used since if the scattered light is very intense, the detectors could become saturated electronically. However, the saturation does not persist since the broad electronic dynamic range and the inherent properties of such detectors will allow it to recover to its normal state without notice. These detectors are used in Microtrac S3500 and Nanotrac and Ultra series because of their sensitivity, optical sensing properties and thermal stability under a wide variety of condition.

PMT (photomultiplier tubes) are very sensitive devices, but because of the high sensitivity, will over-load easily. When overloaded, recovery to a useful electronic condition and functioning may take as long as 20 – 30 minutes. During this period, the instrument will normally be non-functional.

Avalanche photodetectors may also be used, but they too have limitations on electronic capability and range of operation. Once the operating voltage range is exceeded, recovery as with PMT devices takes some time. One method to address saturation in avalanche detectors is to reduce the amount of scattered light reaching the detector. This may be done by reducing the intensity of the incident laser beam by means of an attenuating (reducing) device. Often this adds time to the use of the instrument since adjustments must be made either manually or by instrument command. The adjusting capability of attenuating devices must have a very large range to accommodate the many applications to which the instrument is subjected. Thus the instrument becomes more complex optically and operationally.

What is the difference between an LED and a diode laser? At times confusion arises when using the terms LED and diode laser. The term "LED laser" is confusing since an LED is not a laser and has many properties not desirable in instruments requiring lasers. Both are electronic devices used as light sources, but their applicability to particle size measurement is somewhat different.

As discussed above intensity, divergence and wavelength uniformity are important aspects of light sources being used in light scattering particle size measurements. Particularly in "diffraction" measurements, the number of wavelengths present affects angles of light scattering which is the basis of "diffraction" measurements. A coherent source of light is required and the better the coherence, the better the definition of the light being scattered. LEDs are not coherent light courses. Also, LEDs usually show multiple wavelengths as much as +/-3% of the stated value while diode lasers are typically 0.1 to 0.2%. Use of blue lasers can enhance measurement accuracy as well as sensitivity due to higher intensity, purity of wavelength and much lower beam divergence.