APPLICATION NOTE

Understanding Types of Lasers and Detectors Used in Particle Size Instruments

S35500 / Bluewave / SYNC / Nanotrac

History

Throughout the history of laser particle size measurement many 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 models employing dynamic light scattering measurement of nanoparticles. This note addresses questions that often arise when types of lasers are considered by 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 to exhibit long life and long-term stability for over 20 years.

The longer coherence length is often cited as an advantage of gas lasers. However, for applications in particle measurement technology, the coherence of the laser light from diodes is perfectly adequate. Another advantage is that gas lasers usually require a warm-up phase, while laser diodes can be used for measurements immediately after switching on the device.

What is "Dispersion"?

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. In general, dispersion describes the dependency of a material property on the wavelength. In optics, this is usually the refractive index. Dispersion is a property of a material not of laser design. Often dispersion is confused with beam divergence.

In particle technology, dispersion also means "to separate particles from each other", so that they are available for measurement. This includes breaking up agglomerates, e.g. with ultrasound or compressed air. Sample delivery modules for diffraction analyzers are therefore often called "dispersion modules".

What is "Divergence"?

Divergence is defined as the increase in beam diameter with distance from the aperture. Gas laser beams can diverge 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 use a specially selected lens to achieve a nearly non-divergent beam. Collimated beams of light are said to exhibit very small divergence.

What is "Coherence"?

Coherence 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.

Why does Microtrac use silicon detectors in Light Scattering?

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 because 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. These detectors are used in Microtrac S3500 series, SYNC and Nanotrac analyzers because of their sensitivity, optical sensing properties and thermal stability under a wide variety of conditions.

Photomultiplier Tubes (PMT)

PMTs are very sensitive light detectors, 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

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 sources. 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.

For further information please contact us at:

www.microtrac.com