The Instrumatics Quadbeam™ Alternating Light Principle for Suspended Solids Measurement

The purpose of the Quadbeam™ Alternating Light Principle design is to improve the measurement reliability of optical turbidity and suspended solids instruments. Instrumatics sensors that use Quadbeam™ technology to compensate for most sources of measurement error, provide unrivalled accuracy and reliability when compared with competitive systems.

The Quadbeam™ Alternating Light Principle is based on a fundamental method of suspended solids measurement: suspended solids can be measured by shining a light of known intensity a fixed distance through a medium at a photocell detector. Suspended solids in the medium attenuate some of the light. The detector current gives a measure of the attenuation by the medium, that corresponds to suspended solids concentration and turbidity measurement.

The optical method of suspended solids measurement depends on several variables, including light source intensity and detector sensitivity. Variations in these parameters will introduce errors.

Causes of light source variation:

- Dirt accumulation
- Ageing
- Voltage variations

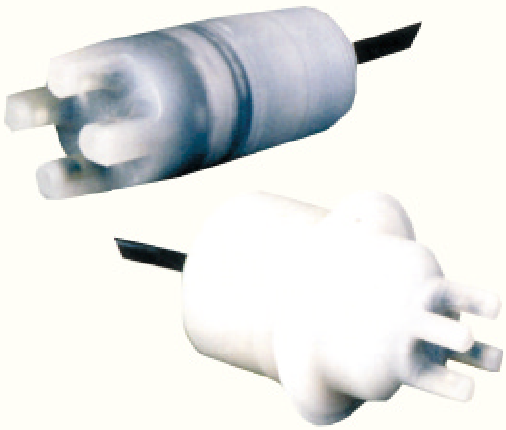
Causes of detector variation:

- Dirt accumulation
- Ageing

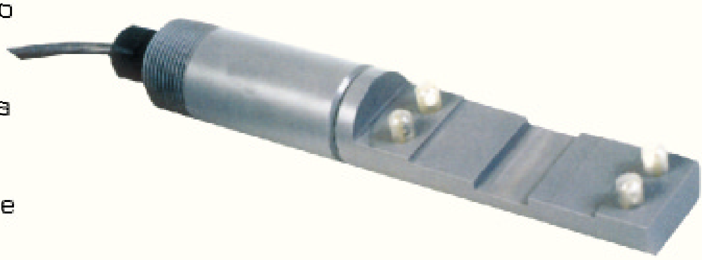
The alternating light principle of suspended solids measurement has been known for many years, so we make no claim to its originality.

The Quadbeam™ principle of light attenuation is a superior method of measuring suspended solids whilst the 90 degree light scattering principle (ISO7027) is the preferred principle for low range turbidity measurements. Because most instruments designed to conform to ISO 7027 are single beam they rely on mechanical cleaners to maintain the validity of the measurement. Quadbeam sensors rarely require external cleaning devices.

MSSD33 Suspended Solids Detectors



Series 20 Suspended Solids Sensors



Series 90 Suspended Solids Sensors

Development of the Quadbeam™ Alternating Light Principle

One Light-One Detector

The fundamental method of optical suspended solids measurement is shown in Figure 2. Light (L) strikes a photocell detector (E) that generates an electrical current (I). The detector output current (I) is a function of the intensity of the light source (L), the detector characteristics (E), the distance between the light source and the detector (X) and absorption by the medium (á).

Although the distance between the light source and detector is fixed, uncontrollable variations in both light intensity and detector sensitivity can still be sources of error. There is no compensation for reduced system performance due to component ageing or contamination. For example, if the light intensity is reduced by accumulated dirt on the light source window, the smaller signal received by the detector will be interpreted by the system as an increase in suspended solids concentration.

One Light-Two Detectors

Measurement accuracy of a one light one detector system can be improved by adding a second detector at a greater distance (X_2) from the light source (Figure 3). Since physical law dictates that light intensity decreases as a function of distance, the output of the more distant detector (E_2) will always be lower than the output of the closer detector () because it will receive less light.

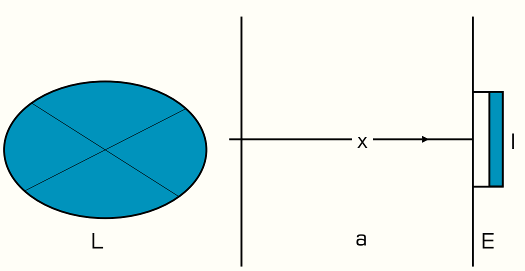


Fig 2 One light and one detector

The output of both detectors expressed as a ratio, Ix_1/Ix_2, is a measurement value that depends on absorption by the medium but does not depend on light source intensity.

$$Ix_1 = 80\mu A$$

$$Ix_2 = 40\mu A$$

$$\frac{Ix_1}{Ix_2} = \frac{80\mu A}{40\mu A} = 2$$

The ratio increases with an increase in absorption. Distance is not a variable because both distance values are fixed. This method compensates for light variation. The ratio remains constant if light reaching each detector is also reduced by 25%

$$I\,x_1 = 60\mu A$$

$$I\,x_2 = 30\mu A$$

$$\frac{Ix_1}{Ix_2} = \frac{60\mu A}{30\mu A} = 2$$

However, a dirty or ageing detector in the system could produce inaccurate measurement because it would affect the output of only one detector. This variable would be interpreted by the system as a change in suspended solids concentration.

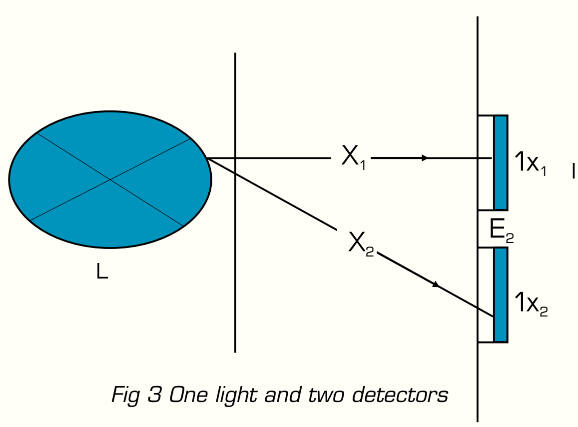


Fig 3 One light and two detectors

Two Lights-One Detector

Measurement accuracy of the one light one detector system can also be improved by using one detector with two light sources switched on and off alternately (Figure 4). The detector signals, expressed as a ratio Ix_1/Ix_2, provide a measurement value that depends on absorption by the medium but does not depend on detector sensitivity.

$$Ix_1 = 80\mu A$$

$$Ix_2 = 40\mu a$$

$$\frac{Ix_1}{Ix_2} = \frac{80\mu a}{40\mu a} = 2$$

Again, the ratio increases with an increase in absorption and distance is not a variable because both distances are fixed.

This method compensates for changes in detector sensitivity. Any reduction in detector sensitivity lowers the input from each light source by the same factor and results in a constant ratio. However, light intensity variation caused by dirt accumulation, ageing of the light source or a fluctuation in voltage would produce inaccurate measurement because it might reduce the intensity of only one light source.

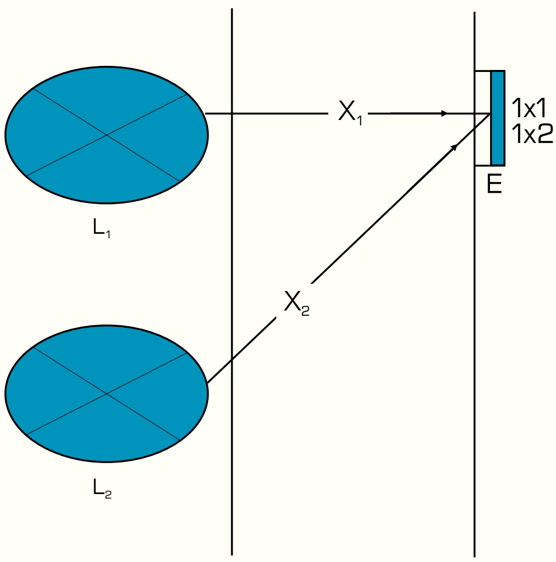


Fig 4 Two lights and one detector

Two Lights Two Detectors

The Quadbeam™ Alternating Light Principle compensates for variations in both light intensity and detector sensitivity. It features two detectors with two light sources switched on and off alternately (Figure 5).

When L_1 is on, light is transmitter through the process media and each photodetector (E_1 and E_2) receives the light, via paths X_1 and X_2 respectively. E_1 and E_2 generate signals based on the amplitude of light each receives. A ratio (R_A) is created by comparing these two signals.

$$R_A = \frac{Ix_1}{Ix_2} = \frac{80\mu a}{40\mu A} = 2$$

Because any change in the characteristics of L1 (due to age or contamination will affect E1 and E2 equally, this ratio will remain the same. This eliminates the effects of contamination on L1.

$$R_A = \frac{Ix_1}{Ix_2} = \frac{60\mu A}{30\mu A} = 2$$

The same procedure is performed using L2 across paths X_3 and X_4, and a similar ratio (R_B) is created. This eliminates the effects of contamination on L_2.

$$R_B = \frac{Ix_3}{Ix_4} = \frac{30\mu A}{60\mu A} = 0.5$$

To eliminate the effects of contamination or component ageing on the detectors, a ratio comparing R_A and R_A is made.

$$\frac{R_A}{R_B} = \frac{2}{5} = 4$$

Because a change in the sensitivity of E_1 or E_2 (due to age or contamination) will reduce the light received from L_1 and L_2 equally, this ratio remains constant even if the characteristics of E_1 or E_2 change. For example, if dirt covers 25% of E_1, the light received from both L_1 and L_2 will be reduced by 25%, but the ratio will remain the same.

$$R_A = \frac{Ix_1}{Ix_2} = \frac{60\mu A}{40\mu A} = 1.5$$

$$R_B = \frac{Ix_3}{Ix_4} = \frac{22.5\mu A}{60\mu A} = 0.375$$

$$\frac{R_A}{R_B} = \frac{1.5}{.375} = 4$$

By using these ratios, rather than the direct output from E_1 and/or E_2, the effects of contamination and component ageing are eliminated.

Ambient light is detected by E_1 and E_2 while L_1 and L_2 are off. The resulting "offset" signal is used to correct the measurement. All signals are linearised and combined to produce a reliable 0/4-20mA output signal which is proportional to solids concentration.

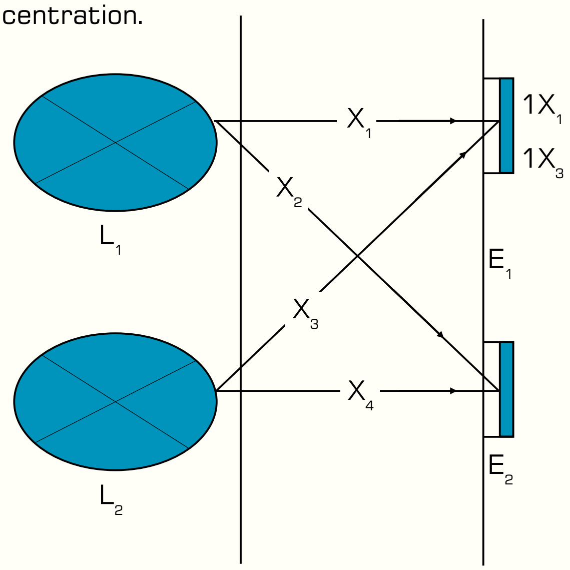


Fig 5 Two lights and two detectors- Instrumatics Quadbeam™ Alternating Light Principle

Instrumatics designs Quadbeam™ sensors of different sensitivity and measuring range by changing the distances between the sensors light sources and detectors. When they are far apart, the sensor is more sensitive to suspended solids because the longer optical path lengths increase the sensors ability to detect small changes in suspended solids concentration.

Because an increase in distance reduces the amount of detected light intensity, optical path length also determines the measuring range. For example, in two sensors with identical light sources, the sensor with longer path lengths will detect less light therefore it reaches the upper limit of its measuring range at a lower concentration and has a smaller measuring range. The sensor with shorter path lengths can measure higher concentrations and has a larger measuring range.

Instrumatics offers a variety of Quadbeam™ optical sensors and instruments for accurate measurement of most turbidity and suspended solids ranges.