Line Scan Primer AN-0401

Introduction to Diversified Optronix

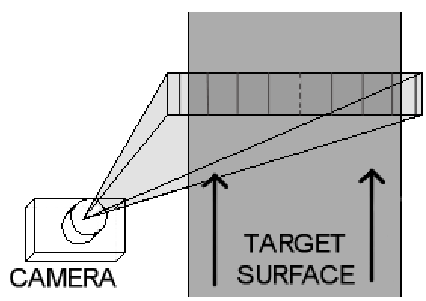
Diversified Optronix specializes in optically based, non-contact measurement and analysis systems:

- **Line Scan Measurement System** – Cost effective inspection, measurement, and flaw detection of web-based, extrusion and other continuous product streams. System outputs include digital displays, analog outputs, limit-alarm relay outputs and serial data outputs.
- **OptiView** – Viewing, analyzing and measuring of periodic, repetitive motion—such as reciprocating, vibrating, or rotating machinery—in apparent slow or stopped speed. System output is NTSC video to a monitor or recorder.
- **Displacement Follower** – Non-contact viewing, analyzing and measuring of any type of linear or two-dimensional motion. 10KHz bandwidth. System outputs are analog voltage outputs.

These products evolved from those of Optron Corp. Diversified Optronix Corporation was formed in 2003, and focuses on these products acquired through Diversified Engineering.

Diversified Optronix Series 200 Line Scan Measurement System

Custom optics allow the Series 200 Line Scan System to monitor products of almost any size. Its 5000-pixel resolution is imaged over a linear Field-of-View (FOV). In effect, it is a non-contact electronic ruler with 5000 gradations. Each gradation, or pixel, represents a specific dimension of the imaged target cross section.



A single camera covering the full width of the target. Arrows show target motion.

The optical magnification and the sensor's pixel size determine the dimension represented by each image pixel. The dimension represented by each pixel and number of sensor pixels determine the width of the FOV in the target plane. Target size can range from millimeters to meters depending the optical arrangement. The System can be configured to work with a large variety of applications in manufacturing and production.

A base system includes camera and field-configurable controller. System outputs include local digital displays, analog outputs, limit-alarm relay outputs and serial data outputs. The controller supports up to four simultaneous measurements and provides multiple output formats for each of the four measurements. A second camera is an option for applications requiring accurate edge-to-edge measurement of large objects. The system is self-contained and requires no external components to acquire and process a measurement.

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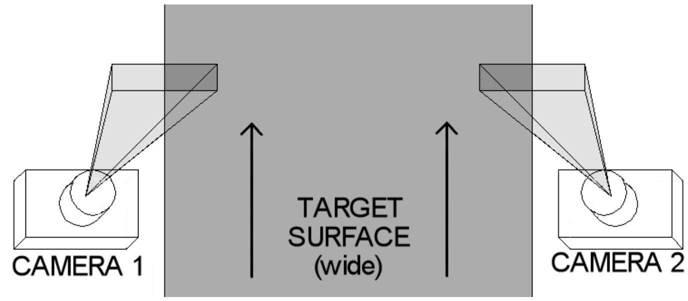

Two cameras covering only the edges of a wide target. The arrows show the direction of motion of the target.

Overview of Line Scan Applications

The systems are useful in manufacturing operations for flaw detection, dimension measurement, and position measurement in web-based, extrusion, and other continuous production streams. Line Scan Systems are used in the manufacture of steel, aluminum, rubber, paper, plastics, textiles, integrated circuits, and medical devices. The combination of 5000-pixel resolution with the ability to provide simultaneous flaw inspection, multiple measurements, and position control information provides cost effective solutions to common manufacturing inspection needs.

Custom-selected lighting and optics along with field-configurable Controller software make the Line Scan System adaptable to many applications. A sample application might be:

- Continuous measurement of the width of a metal sheet, with alarm outputs if the width falls outside allowable values
- Analog output proportional to the centerline of the sheet as an input to a position control system
- Monitoring the position of required features
- Flaw inspection with alarm outputs if flaws larger than a given size are detected

A generalized description of suitable applications parameters would include:

- Has either features or potential flaws with edges that can be identified by two-tone contrast
- Does not require two-dimensional pattern recognition
- Requires accuracy in placement of features
- Requires immediate display or indication of measurement results, and/or serial data output of all measurements to a host computer

Line Scan Sensor Theory

The Line Scan system uses a line-scan camera based on a *linear* image CCD sensor. The sensor takes a high-resolution *line* image of the target. A typical linear CCD array has thousands of light sensors arranged in a line. Each individual sensor captures a pixel (a picture element) of the imaged target object. The resulting image is one pixel high and thousands of pixels wide. The Diversified Optronix Line Scan System resolution is 5000 pixels.

The resolution of area scan CCD sensors is usually significantly lower than linear CCD arrays. Many video cameras use area CCD array image sensors to capture an image with a pixel resolution of 640 x 480, or 1024 x 780. Higher resolutions are available, but the costs are noticeably higher with increasing resolution and image capture rates. High resolution and rapid capture rates are mutually exclusive in most cost limited applications.

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Line Scan Application Theory

The Diversified Optronix Line Scan Systems target applications in which the high-resolution line image of the linear CCD provides most or all of the information needed to make a measurement or inspection decision. These Line Scan systems provide a highly cost-effective solution for applications where a few lines of information provide all the required data. The target material is moved past the linear FOV of the Line Scan camera at a reasonably constant rate. The Line Scan System acquires repeated images across the width of the moving material and makes a continuous series of measurements. Filtering and averaging are optional functions.

In contrast to Line Scan cameras, Area Array cameras and sensors are needed when an inspection or analysis task requires that an entire image *area* be examined or processed as a whole. In these cases, the interpretation of any pixel is influenced by many other pixels within the area of the captured image. This type of system requires image capture and digital processing electronics, and becomes increasingly complex when high sample rates are needed. A linear image sensor, however, can build an area image by combining successive lines into a 2-D area image. Although still complex, this can yield a more flexible or cost-effective solution for some applications.

Line Scan resolution is hard-limited by the number of pixels in the sensor. The desired linear FOV in the target plane is imaged onto the linear CCD sensor. The FOV divided by the number of sensor elements in the array yields the raw resolution of the system. For example, a 125 mm (~ 5”) linear FOV imaged onto the 5000-pixel array results in each pixel being illuminated from a 25 micron (~ 0.001”) square of the target, since the sensor elements are square. With appropriate optics and camera-to-target spacing, a FOV from 10 mm to several meters is easy to achieve. The quality of the imaging optics, lighting, angle of view, and movement of the target object also affect resolution. Vibration of the sensor itself can degrade measurement accuracy.

Lighting

Providing the correct lighting is an important step in deploying a successful measurement application. Backlighting of an opaque object is the easiest method of illumination. Front illumination is uncomplicated when the target provides sharp optical contrast on the features or edges to be measured. However, in some cases high-intensity, directed, focused, or angled lighting is needed. Monochromatic, near infrared, and near UV light sources can be used to increase the optical contrast of target objects.

Transparent Objects

Transparent objects are challenging, but other optical properties can be exploited to distinguish the target features. For instance, a glass cylinder sharply refracts light passing through its outer edge when the light has a nearly-tangent angle of incidence.

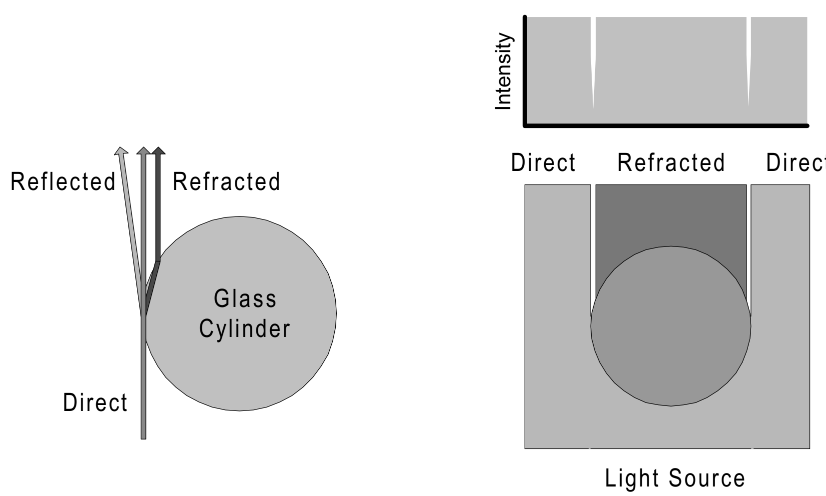

Illustration of light passing through glass cylinder

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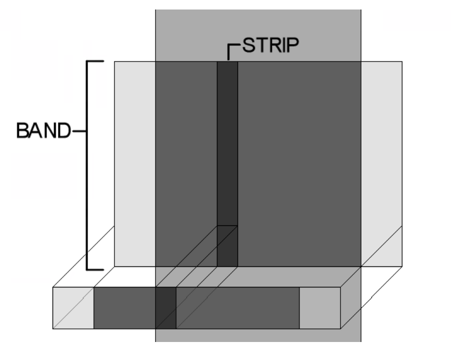
The result is a discontinuity or gap in the otherwise uniform light intensity across a cylinder illuminated from behind. Both the inner and outer edges of glass tubing may be detected in this manner. The effect occurs on any transparent material with a curved edge, but there are practical limits. Thin sheets of transparent material with a sharply-cut edge are difficult to image. In these cases, the wavelength, polarization, or directivity of the illumination must be adjusted to develop the required contrast.

Scan Time

The scan rate governs how much light is gathered or integrated between scans. The image acquisition time (exposure time) is equal to the scan time, which is simply the reciprocal of the scan rate. Faster scan rates allow more measurements per inch on a moving target, but gather less light. The scan time can be set from 1ms to 100ms, with corresponding scan rates from 1KHz to 10Hz.

Rapidly moving targets impose significant restrictions on small FOV applications. For example, target material moving at 3 meters/sec (~ 120 in/sec) travels 3mm in 1 millisecond, which is the shortest image acquisition time. This may be larger than the size of the imaged pixel, and will limit the resolution in the direction of material travel. However, small holes, flaws and voids in the material are still detectable because the sensor's pixels integrate light from any flaw passing through the FOV. Light from the entire band is accumulated during the scan time, and a bright source of illumination can compensate for the reduction in the light from a hole that persists for less than the image acquisition time.



Each pixel of the linear array is projected onto a band of fixed width and height for each scan. The speed of the target multiplied by the scan time gives the height of the band. A pixel accumulates the Integrated light from the entire band

Field of View

To minimize errors caused by off-axis viewing, a rule of thumb is to keep the FOV less than two-thirds of the target-to-camera distance. This is not a strict requirement, but will minimize measurement errors across the FOV. A 50mm focal length lens meets these requirements and delivers an angular FOV of roughly 38 degrees when used at typical focus distances. The angular FOV decreases noticeably as the focus distance drops below four times the focal length of the lens—about 8" for a 50mm lens.

Wide-angle lenses (shorter focal length) may be used to get a larger FOV without increasing the target-to-camera distance, but some amount of geometric distortion, with accompanying measurement errors, will develop at the image boundaries. Telephoto lenses (longer focal length) may be used to allow increased target-to-camera distances while keeping the same FOV.

Summary

The Line Scan System is one of several high-quality, non-contact, optically-based measurement and analysis systems offered by Diversified Optronix. The Line Scan System is a solution to a wide variety of problems in the realm of production measurement and inspection. Whenever low cost, high accuracy and application flexibility are important factors, the Diversified Optronix Line Scan System is *the* answer.

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