The newest system introduced by Lasor/Systronics is the 2f1 Vision System, which both detects defects and measures the optical quality of glass ribbon and plastic sheet. By incorporating a new illumination and sensor unit, Lasor/Systronics inspection system is able to look for defects on 100 per cent of the web and obtain both the distortion and the deformation in two directions in a single unit. The defect and optical information can be displayed and transferred to subsequent marking and/or cutting devices for optimum material utilization.

**Standard system for detection of defects and distortion**

The principle of maximizing output is essential in any manufacturing process to maintain low cost production and to continually enhance customer confidence through quality production. The 2f1 inspection system was developed for the glass and plastic sheet to address these needs (Plate 1).

The 2f1 detects defects and measures the optical quality of the sheet. By incorporating a new illumination and sensor unit, Lasor/Systronics inspection system is able to look for defects and obtain both the distortion and deformation in two directions in a single unit. The defect and optical information can be displayed and transferred to subsequent marking and/or cutting devices for optimum material utilization.

The two-phase configuration measures the distortion in one direction while the four-phase configuration measures the distortion in two directions (in the direction of movement and across the belt). Owing to its compact construction, this unit requires only 1m space in machine direction, saving precious space on the production line.

The 2f1 Vision System integrates the capabilities of the two systems, coming together on a common platform with new technology based on CCD cameras and intelligent illumination. The result is a detection and measuring system which was developed to fulfill two requirements within one unit. Specifically, the system measures point defects (deformation) and optical qualities in real time simultaneously.

With the help of the 2f1, it is now possible to get information about defects and
Measuring principle of the 2f1 Vision System

The function of the 2f1 is to measure the deflection and absorption of light which passes through a material to be examined. The system consists mainly of an illumination unit below the material and an imaging system situated above the material (see Figure 1 for details).

The LED-based illumination is a light source which can be electronically switched to a two- and four-phase configuration so that one phase is always opposite the other. The high frequency guarantees the full online scan of the glass or plastic up to a speed of 30m/min. Each LED is 0.5mm in diameter and they are spaced 1mm apart.

The material is inspected via a CCD camera looking directly through the glass or plastic on the illumination unit. The size of one pixel seen at the glass surface is 0.1mm × 0.1mm with each line scan camera having a 510mm scan width. A maximum of 12 cameras can be used.

Figure 1 Measuring principle of the 2f1

LEDs usually have a long lifetime (more than ten years). The utilization of this type of illumination allows the glass or plastic manufacturer to reduce the basic maintenance costs.

Owing to the measuring principle, the system is not sensitive to ambient light like other inspection systems. The compact construction allows a space requirement of only 1m in flow (machine) direction.

The camera signal including the defect information is analyzed in the following hardware by use of several mathematical operations. The extracted defect information is displayed on a user-friendly software with multiple features such as rolling defect map, gray scale image and statistical functions, displayed as numerical and graphical data. Only one PC is necessary to run the whole system.

Signal processing

If the camera looks directly through the material to the illumination unit, three different situations can be distinguished from the different signals (Figure 2):

1. With good material, the intensity seen by the camera at a time \( t_1 \) is \( I_1 \). Since only one phase is active at a time, the signal is 50 per cent of the total signal. The other phase gives also 50 per cent of intensity for signal \( I_2 \). The sum of both intensities is the maximum intensity (256 digits) for normal defect free material. Therefore the difference in amplitudes is \( \Delta = 0 \).

2. If the material is faulty due to a deforming defect, both signal intensities change. Seen from the camera viewpoint, the field of view is shifted on the illumination in

Figure 2 Signal processing with (a) no defect; (b) defect signal; and (c) dirt
the direction of material flow. This leads to an intensity loss of signal $I_1$ and an intensity increase of signal $I_2$. The reason is the optical deflection caused by faulty material. The difference for this case is $\Delta \neq 0$.

(3) With dust or other absorbing influences in the material, both intensities decrease. The sum of $I_1$ and $I_2$ is less than 256 digits. With a dust suppressor, it is possible to ignore such absorbing influences and therefore distinguish dust from real defects. The difference in intensity here is $\Delta = 0$.

Owing to the measuring principle and the intelligent illumination, it is possible to measure simultaneously in the material flow direction ($y$-direction) and across the material flow direction ($x$-direction). That means that small lines or reams with deflection in $x$-direction can be found and classified parallel to point defects in the $y$-direction.

The obtained resolution according to this measuring process is 0.1 mm and will be kept constant by an automatic adaption of the scan frequency relative to the speed of material and its transmission rate.

**Measuring results**

The analysis of the camera signals is parallel in $x$- and $y$-direction. Triggered by the scan frequency, defect information is collected. Digitalization and compensation are performed through electronics in the hardware. As a result, the sum and the difference of two following scans are computed to determine the difference.

Three different thresholds are being used to extract the defect information: the bright field (sum of scans), the deflection (difference of scans) and the refractive power (first deviation of deflection). From the order of crossing these thresholds (adaptable by the user) a so-called run-length-code is generated for each scan. Using this code the following software is able to display a complete image of a defect.

An example for the calculation process is shown in the following. Starting point is a gray scale image of a typical deforming defect (Plate 2).

Figure 3 shows this defect graphically as a 3-D image. It shows the deflection signal which is obtained by the formation of the standardized camera signals. Owing to the deflection there are areas with plus and minus signs showing positive or negative deflection.

In Figure 4, the center line is shown to demonstrate the distribution of the signal.

**Plate 2** The example defect

**Figure 3** Typical deforming defect 3-D image

**Figure 4** Center line signal distribution
The amplitude in the center area is zero. In this area, the core of the defect is displayed. As is seen from the figure, no deflection is visible. The size of the core is obtained by the bright field information.

Figure 5 shows the first deviation of the standardized camera signal which is proportional to the refractive power in mdpt (milli-diopter – a unit of measure of the refractive power of glass). An online monitoring of the values for the whole material is available to give permanent information to the user.

If this signal is made with absolute values (Figure 6), the diameter of the defect can be obtained. Depending on the adjustable thresholds, the size of defects can be adapted to existing manual test procedures and the human eye.

**Conclusions**

- The 2f1 Vision System fulfills the combined customer need for defect detection and optical measurement in a compact system with a fast payback.
The measurement of defects and optical quality is now feasible with the 2f1 system. The new revolutionary intelligent illumination concept makes the system flexible enough to measure deflection in the x- and y-directions simultaneously. This enables the manufacturer to see spot defects, while performing optical measurement at the same time.

- The online display (Figure 7) of defect information and statistical analysis provides the manufacturer with extensive information to manage the process. The displays can be customized to the users’ needs.
- The system is expandable to the required inspection width.
- The 2f1 is also available as a laboratory version or for individual sheet inspection.

### Software description

A description of the software can be found in Table I.

### Table I: Software description

<table>
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<th>Screen presentation</th>
<th>Statistics</th>
<th>Connections</th>
<th>Database</th>
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<td>Point defects (profile)</td>
<td>Data transfer to</td>
<td>Data transfer takes place every 50cm to an internal database (access file). The data of one day are stored in day-file, total storage for one year where three data groups are stored:</td>
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<tr>
<td>Rolling defect map including spot defects</td>
<td>All defects (cumulated) (up to eight classes) are displayed across the ribbon with 16 tracks for various points of time according to their type</td>
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<td>Potential-free outputs</td>
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<td>Optics (trend)</td>
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