# IQPC$^{blu}$: forward-thinking inline-inspection

**Quality assurance will always be an essential element of the in-line scanner's functionality. However, the scanning cycle can be used much more constructively, providing valuable feedback for active process control.**

## Introduction

Optical scanners have played an important part in the disc production process for the past twenty years. In its most basic form, in-line scanning was employed simply to provide a pass or fail decision, but as the disc production process has become more sophisticated – and more competitive – the demands placed on scanners have included faster inspection time, better optical resolution, improved user interface and data archiving facilities.

Early recognition of variations within the process reduces costs and saves time. Statistical information and trend analysis provided by in-line scanners can alert the operator when production is running towards the limit of the process window, enabling corrective action to be taken before substandard discs are produced.

## The Quality Concept

The traditional view is that higher output can only be achieved by compromising quality standards. This view is based upon the philosophy that manufacturing quality product means simply throwing away inferior product, thereby decreasing productivity and increasing manufacturing costs.

However, manufacturing quality product does not necessarily conflict with the goal of reducing costs. This can be understood by considering the quality function. Quality cannot be described simply by a pass/fail decision: 100% quality if the deviation from the target is within the specified limits, 0% quality otherwise. Instead, quality is a continuous function of the deviation from the target value. Any deviation from the target value means a loss of quality, even within specified limits: products close to the specification limits have a poorer quality than those close to the target value, while products outside the specification limits have an unacceptable quality. Observing this quality function in more detail can be used to control – and improve – quality within the process window. Because this control is performed within the process window, quality is improved and there is no decrease in yield.

## The Challenges

With the advent of new media such as the Blu-ray Disc, and continual improvements to production equipment and processes, the demands placed upon test and inspection equipment become increasingly rigorous. The production of high-density formats necessitates a highly accurate scanner, able to detect new types of defect which are often much smaller than those found when manufacturing established formats. In addition, image processing must be improved to meet the requirement of handling more data within a shorter cycle time.

dr.schwab Inspection Technology's development team has been working closely with production equipment manufacturers and replicators to identify the issues which they face on a day to day basis, and to find ways of improving productivity and cost-effectiveness by the application of innovative test technology. The **I**ntegrated **Q**uality and **P**rocess **C**ontrol System (**IQPC$^{blu}$**) is the fourth generation of in-line scanners produced by the company, and encompasses all the requirements of a state-of-the-art in-line test tool.

## Illumination

When designing the **IQPC$^{blu}$**, the team went back to basics. Hardware architecture is fundamental to the performance of a scanner, with the optical path and light source playing a critical role in its success.

The light source must be carefully selected to provide the optimum combination of features for effective inspection: stable spectral properties, durability, and sufficient intensity for a good signal-to-

noise ratio to generate the high contrast images essential for accurate defect classification. The optical path must be optimised for contrast, sharpness and minimal image distortion.

Solid state LEDs provide the ideal solution for **IQPC$^{blu}$**, and offer several advantages over halogen light sources:

- LED illumination is highly efficient, using only a fraction of the power required by a halogen bulb and eliminating problems associated with overheating. Not only can excess heat be detrimental to disc quality – causing deformation and harming coating layers – but it can also destabilise the scanner's electronics.
- A LED produces light in the 'forward' direction which – like a laser - can be utilised more efficiently than the diffuse light produced by a halogen bulb.
- LEDs deliver a constant light output over a long period of time, especially when implemented with closed-loop feedback. The intensity of halogen light falls with time, necessitating regular recalibration. In addition, the operating life of LEDs is significantly longer than halogen bulbs.
- The diameter of a LED is approximately five times smaller than that of a halogen bulb, making the LED closer to a point light source. The scanner is therefore more sensitive to defects - such as bumps and bonding gaps - which are detected by a very small light deflection.
- A blue LED can be implemented, its shorter wavelength making the scanner highly sensitive to pit and groove structure defects especially for Blu-ray Discs with very shallow pits and grooves. The blue LED also improves the detection of defects at certain layers. For example, the reflectivity of the uninitialised recording layer of rewritable disc formats is minimal for red light, with most of the reflected light coming from the substrate's surface; the contrast of local defects in the recording layer is therefore extremely low. However, reflectivity is maximised for blue light, resulting in maximum contrast for defects in the recording layer and optimum defect detection.
- Only a very small part of the spectrum produced by a halogen bulb is usable blue light; when combined with the spectral sensitivity of the CCD camera, its power becomes negligible. Blue LED illumination enables the scanner to benefit fully from the advantages of blue light.

To obtain clear signals at the CCD camera receivers it is important to achieve an even radial distribution of light intensity. **IQPC$^{blu}$** utilises an innovative arrangement of single wavelength light sources, purpose-built lenses and beam-splitters, which enables a combined single optical path for infrared and blue light with the ability to detect and analyse defects which are not visible using other optical arrangements.

### Measurement Channels

The inspection operations are carried out by individual optical channels:

- Bottom/top: analyses light reflected by the bottom/top side of the disc
- Substrate: analyses light transmitted by a clear substrate
- Blu-ray Disc Substrate: an additional channel for analysing light reflected by the bottom surface of a clear substrate, enabling detection of local defects located on that surface
- Angular Deflection: measures warp and tilt at 8 radial positions
- Space Layer Thickness: measures layer thickness of the bonding resin of dual layer discs at 5 radial positions
- Cover Layer Thickness: measures cover layer thickness of Blu-ray Discs at 5 radial positions
- Optical Density: measures the radial distribution of the optical density (indicating layer thickness) of the dye layer
- Diffraction Order: measures the radial distribution of diffraction order for evaluation of pit or groove structure on clear disc substrates

The **IQPC$^{blu}$** is supplied with a combination of optical channel modules to provide the correct measurement suite for the format – and process stage – specified by the customer.

## Parallel Processing

Within the **IQPC$^{blu}$** each optical channel has its own image processing hardware, with DSPs capable of pre-processing images at the 40MHz pixel clock frequency of the latest digital CCD cameras. Pre-processed data is collected by a master controller inside the scanner, which in turn is connected to a host PC. All inspection and measurement results are presented and stored in the host PC.

This parallel processing concept offers the advantage that the high-speed image processing creates time for the extended statistical and trend analysis required for process control. It accommodates the dual demands of short cycle time and advanced defect recognition.

## Defect Classification

Defect classification provides the basis for interpretation of inspection results for process monitoring and control. The process engineer needs automatic warnings about process instabilities supported by clear information about defect type, severity and frequency.

When an 'event' is detected by the scanner, it is analysed by image processing and characterised by a set of parameters including greyscale values, area, shape, orientation, and position on the disc. The events are checked against a database, in which each known type of defect is classified according to the values of its parameter set. Because the values of a parameter set for a particular defect classification can vary, all values of the defect parameter are allocated a probability factor; the results generated from this algorithm are highly accurate.

The process engineer is able to set limits and thresholds for each defect classification, which contribute to the criteria for disc sorting and statistical analysis.

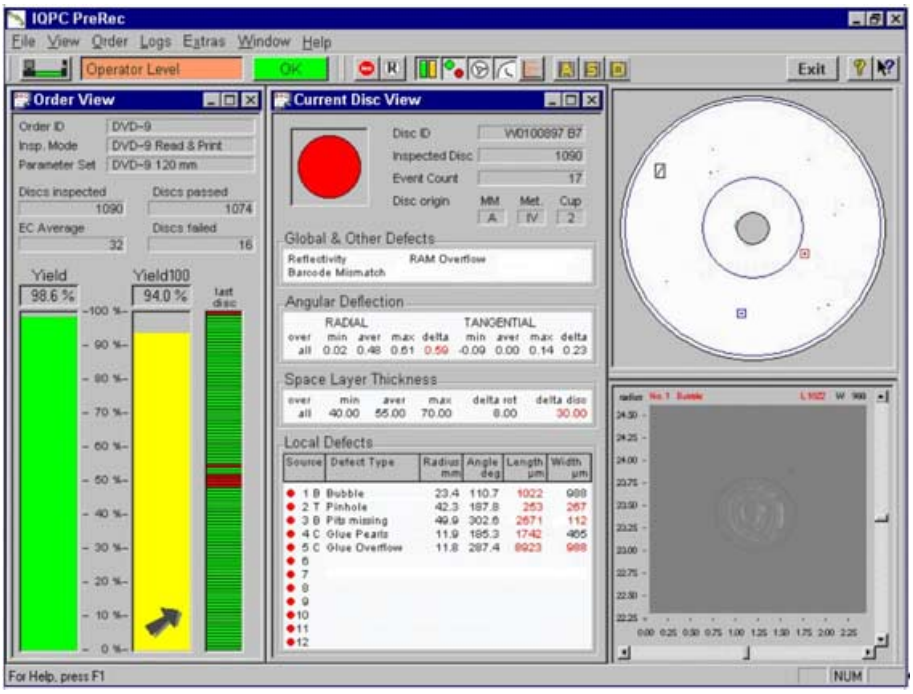


*Fig 1: Accurate defect detection and classification*

Certain defects – and trends in measurement results - are characteristic of particular contributory factors within the manufacturing process: early recognition through accurate defect classification and trend analysis provides the opportunity for cost-saving pre-emptive corrective action.

## User Interface

The **IQPC$^{blu}$** user interface is totally Windows-based, and offers a variety of options for display, analysis and archiving of inspection results. The host PC can run up to three scanners simultaneously: if the scanners are integrated into a single production line (eg: substrate, dye and final scanners in a line producing recordable media), the order yield and yield for the last 100 discs can be displayed.

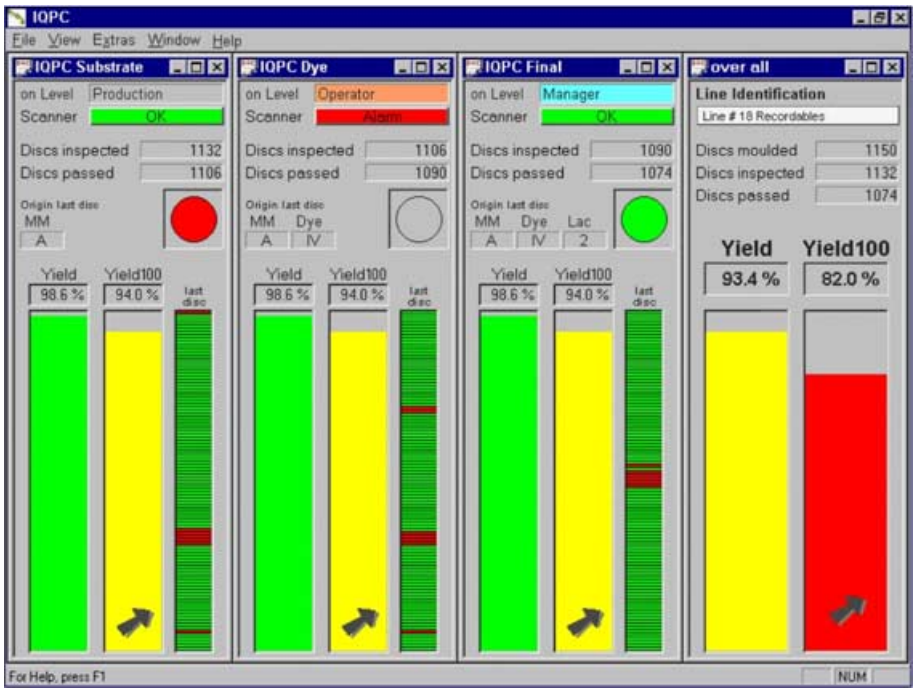


*Fig 2: Up to three scanners can be controlled simultaneously by one PC.*

The long-term stability of the process can be monitored and controlled. By setting appropriate thresholds, a warning message is generated when the process moves towards the limits of the process window, offering the engineer the opportunity to take corrective action before substandard discs are produced.

## User Benefits

The innovative design of the **IQPC$^{blu}$** delivers real advantages:

- LED illumination and an optimised light path ensure clear signals with high contrast for accurate defect recognition. By using a combination of infrared and blue light, defects can be detected which are invisible to other systems.
- Improved defect classification generates more detailed and accurate process information, making it easier for the process engineer to make adjustments. Process events that affect the quality of the finished disc can be seen more quickly, with the opportunity to take corrective action before substandard discs are produced.
- The modular design makes it easy to adapt the scanner for all formats – current and future – and for inspection at any stage of the replication process. Closed-loop controlled LEDs and robust engineering contribute to a reliable and low-maintenance system.
- Parallel processing hardware architecture for an ultra-quick inspection cycle, creating time for statistical and trend analyses, plus a margin for the faster cycle times anticipated in production lines of the future.

## Conclusion

The **IQPC**$^{\textbf{blu}}$ demonstrates that – even for mature processes - in-line scanning offers far more than quality assurance. Advanced defect recognition and classification together with accurate disc measurement can be harnessed for process control and optimisation.

By applying the 'quality function' concept, the replicator can focus on stabilising the key production parameters within the process window, utilising real-time data from in-line scanners supplemented by off-line testing with, for instance, dr.schwab Inspection Technology's **argus** Universal Disc Measurement System. Pre-emptive process correction raises product quality while increasing productivity and improving yield, saving time and money: good news for the replicator and his customers.

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