Diagnostic Technique for Real-Time Measurement of Optical and Scan Properties of Optical Printheads

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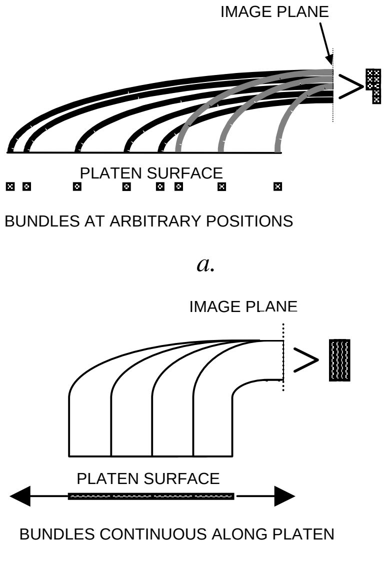
Abstract

A diagnostic technique has been developed for rapid characterization of optical and scan properties in optical printers. The technique provides simultaneous real-time measures of beam profiles, including spot size, centroid and energy, at all or multiple positions along the print scan line for dynamically moving beams in laser printers or for static optical beams in LED printers. As such, it facilitates adjustments of *f*- lenses in laser printheads with air bearing spindles without the need to stop the polygonal scanning mirror. Also, since an entire raster is measured at once, measurements of the scan line bow and linearity characteristics are obtained in real-time. Polygonal scanner jitter characteristics can be measured in seconds. For LED printheads, it provides for optimal adjustment of lens/array assemblies, and for measurement of the many thousands of LEDs in seconds, yielding linearity, MTF, and power compensation values. When compared to conventional slit-scanning diagnostic methods, the 3σ measurement accuracy for spot size is slightly less, but the 3σ centroid accuracy is improved, primarily because there are no moving parts. For instruments using this diagnostic technique, real-time performance yields up to a thousandfold increase in measurement speed, with corresponding reductions in test time, allowing for vast improvement in fabrication tools and in quality control and assurance in printhead manufacturing.

Measurement Technique

The measurement technique, illustrated in figure 1, uses coherent optical fiber bundles positioned at the measurement plane to transfer incident CW or pulsed optical beams to the image plane at the other end. The image plane is proximity focused to one or more cameras for profile image acquisition at the video rate of the camera. This technique allows for multiple positions to be monitored using a single camera, as opposed to conventional techniques using either multiple cameras at the respective measurement locations, or using a single camera or slit scanning instrument that is moved to the respective measurement locations. Also, the technique allows for real-time updates at the camera video rate. Figure 1a shows a design with fiber bundles arranged at arbitrary discrete positions along the print plane, specifically for Laser printhead diagnostics. Figure 1b shows a design for LED printheads, with a continuous array of bundles at the print plane, with small gaps between the bundles. (A mechanical shift of a few hundred microns is necessary to measure the LED spots incident in the gaps.)



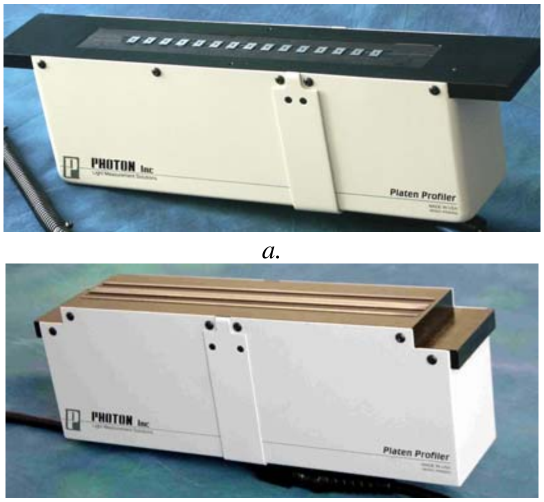
a.

b.

Figure 1. Coherent optical fiber bundles positioned at the scan plane and brought together at the output plane for proximity focusing to a camera. Segmented design for laser printheads is shown in a, and the "continuous" design for LED printheads is shown in b.

Platen Profiler Instrument Development

Profilers have been developed using the designs of figure 1 for Laser and LED printheads. The sensors for these profiling instruments, called "Platen Profilers", (patent pending) are shown in figure 2. Figure 2a shows a unit with 15 sensors, ~1mm ×3mm located on nominal 15mm centers along a 216mm scan line. A single 12-bit 15Hz CCD camera acquires the images at all the locations simultaneously. Figure 2b shows a unit for LED printheads, with 26 sensors, 0.5mm × 8.7mm positioned end-to-end providing 226mm coverage. In this case two 12-bit CCD cameras acquire the images at all the locations simultaneously at the 15Hz camera rate. The images are acquired using digital framegrabbers and the profiles are analyzed in real-time at rates up to 15 Hz on a PC. The 3σ accuracy for $1/e^2$ spot size is typically 5% for a 100μm beam, and ±3μm for position.



a.

b.

Figure 2. Platen Profiler developed by Photon:
a.) Discrete design for Laser Printheads
b.)"Continuous" design for LED Printheads

Laser Printhead Diagnostic A Typical measurement scenario for a Laser printhead is shown in figure 3. The laser driver generates a series of pulses to fire the lasers so the scanned beam is incident upon the respective sensors at the print plane. A laser drive pulse to generate a single spot is typically 10ns in duration, and there are numerous possibilities for the pulse sequence, depending on what characteristic is being measured. For example, a pulse sequence with 15 pulses with appropriate spacing will produce a single spot on each sensor during one raster scan of the polygon (typically ~0.5ms), with the resulting profile data updated at the real-time camera video rate.

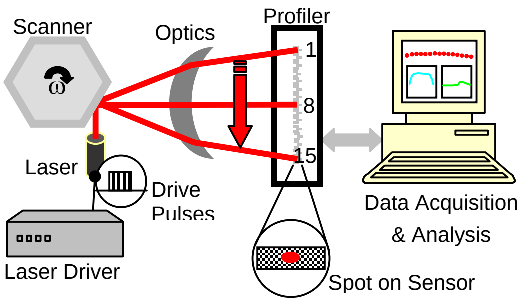


Figure 3. Laser printhead measurement example.

Figure 4 shows an example video screen with 2 spots incident upon each sensor during a single raster scan of the polygon. The acquired spot images are processed to provide beam diameter, centroid position, and energy values. Real-time updates facilitate rapid adjustments of optics, such as f-θ lenses.

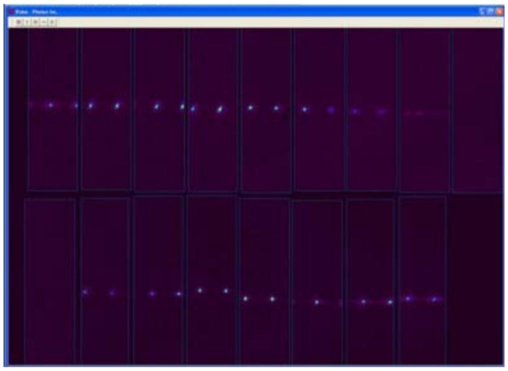


Figure 4. Laser printhead measurement example for Platen Profiler with 15 discrete bundles at nominal 15mm spacing along the scan line and 2 spots on each bundle.

Additional parameters such as Scan Bow and Linearity are then derived from the collective profile parameters for quality control and assurance. Figure 5 shows a software screen that updates in real-time with results for Scan Bow and Linearity derived from a measurement where one spot is generated on each sensor.

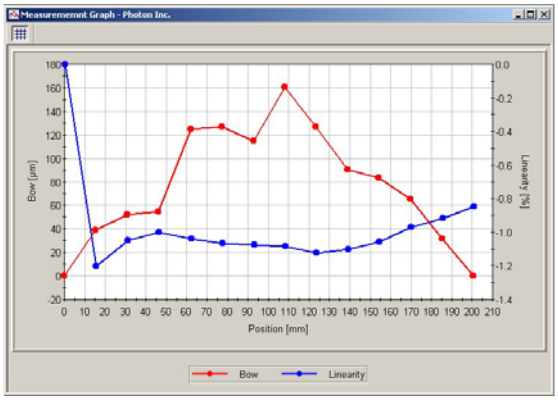
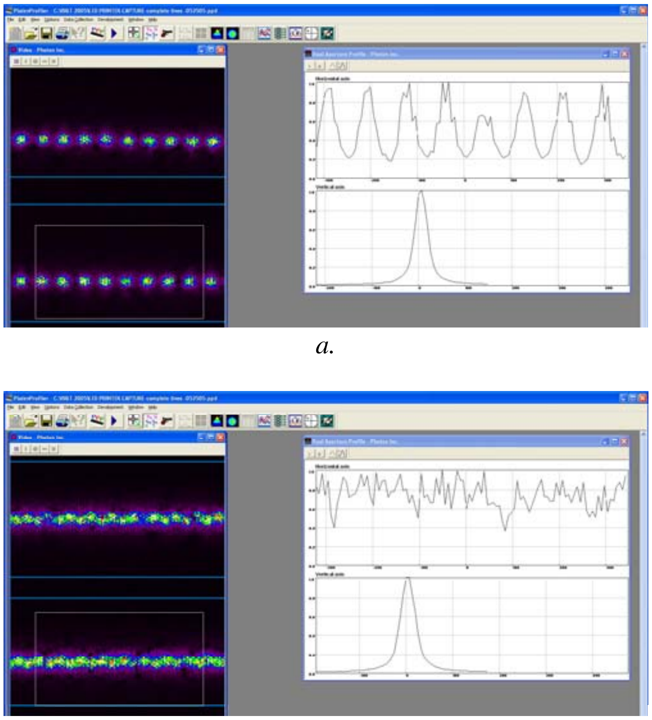


Figure 5. Real-time measurement of Scan Bow and Linearity for a Laser Printhead.

The duration of a laser drive pulse sequence for a single acquisition is equal to the camera video frame time, which for a 15Hz video rate is 66.67ms. Thus, pulse sequences for spots from numerous raster scans of the polygon can be generated to measure characteristics such as Facet Jitter, Facet Tilt, etc. For example, to examine a single facet, a series of single-raster sequences spaced appropriately will generate multiple overlapping spots on each sensor, and the resulting pattern can be analyzed to provide a measure of the Facet Jitter. A continuous train of single-raster sequences will produce overlapping spots from all the facets, and this pattern can be analyzed for Total Facet Jitter.

LED Printhead Diagnostic The real-time performance allows for adjustment of LED array/GRIN Lens assemblies. An example of a real-time software interface for this is shown in figure 6. Figure 6a shows a group of LED spots for the optimum focus condition, and figure 6b shows the same spots in an unfocused condition.



a.

b.

Figure 6. Real-time adjustment of LED array/GRIN Lens Assembly: a.) at focus and b.) unfocused.

When alignment is complete, it is possible to inspect all the LEDs in seconds or less. Figure 7 is an example showing the spots for ½ the LEDs turned on and measured in 66.7ms, yielding beam diameter, position, and power values. Other parameters, such as MTF/contrast, can also be derived, as shown in figure 8. Since there are gaps between the fiber bundles, it is necessary to perform a mechanical translation of either the LED printhead or the Platen Profiler to measure all the LEDs, but even with this requirement a complete characterization can be accomplished in seconds or less.

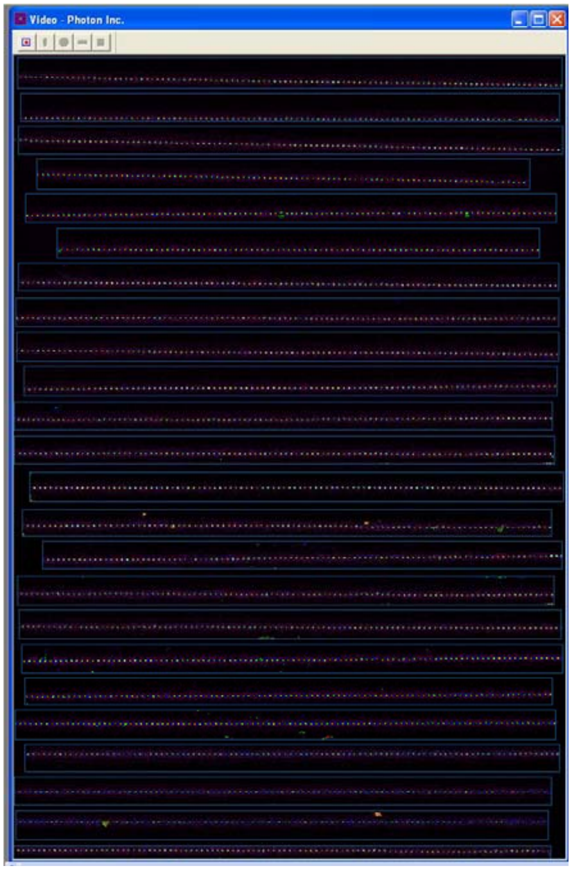


Figure 7. Software video screen showing beam spots for ½ of the LEDs (every other) in the LPH turned on.

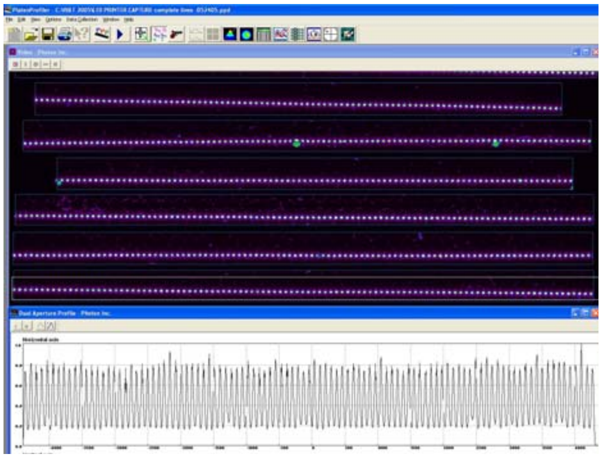


Figure 8. Software profile analysis for one row of the LEDs shown in Figure 7.

Conclusion

The new optical diagnostic technique for optical printheads uses coherent optical fiber bundles to transfer CW or pulsed beam images at the print plane to one or more cameras for simultaneous measurement of the beams at all positions. Instruments based on this technique, called “Platen Profilers”, have been developed for characterizing Laser and LED printheads.

The instrument for laser printheads is able to measure beams in a dynamically operating printhead without the need to stop the polygonal scanning mirror. Using this system the entire single raster scan or multiple raster scans can be acquired and analyzed at once, with a demonstrated update rate of up to 15Hz. This makes it possible to perform, for example, real-time dynamic adjustments of *f*-lenses in printheads with air bearing spindles or to measure the characteristics of polygonal scanners across the entire scan plane in fractions of a second. Since the entire raster scan is acquired at once, meaningful data can be obtained for any polygonal mirror speed. The instrument measures beam spot size, position, and power/energy, and a number of derived parameters including Scan Bow and Linearity, Scan Jitter, Facet Tilt, and more.

The instrument for LED printheads can measure the entire print line at once, with the exception of the gaps between the fiber bundle segments that exclude approximately 2% of the total. Thus it is possible to perform real-time adjustments of the LED array/GRIN Lens assembly for optimum assembly. Due to the finite gaps between fiber bundles, final measurement and characterization for spot size, position and power values, and MTF/contrast for 100% of the LEDs requires a 2-step process that incorporates a slight mechanical translation. This requirement extends the measurement time to the order of a second.

The speed of measurement of the new diagnostic technique allows for real-time adjustment of Laser and LED printhead optical assemblies The corresponding reductions in test time, up to a thousandfold compared to conventional techniques, also sets the stage for vast improvement in fabrication tools and Quality Control and Assurance in printhead manufacturing.

Author Biography

Jeffrey L. Guttman is presently the Director of Technology at Photon Incorporated, a manufacturer of beam diagnostic instruments for lasers and fiber optics. Prior to Photon, he was at Enertech Consultants and the Lockheed Palo Alto Research Laboratory. Dr. Guttman received the BSEE from the Illinois Institute of Technology, and the MS and PhD degrees in Electrical Engineering from the University of Illinois at Urbana-Champaign. He is a member of IEEE, APS, SPIE, and OSA.

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