High Speed Laser Scanning Unit (LSU) Using 12-Beam Laser Diode Array and Image Tracking System (ITT) for High Quality Color Printing

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Abstract

The exposure system of the digital printing engine transforms the digital image data stream into a charge image on the Photo Imaging Plate (PIP). The system developed by HP-Indigo is based on a conventional scanning unit design principal. It consists of laser light source, collimator, polygon scanner and anamorphic F-θ scanning optics. The uniqueness of this system is in the combination of very high process speed (1.2 m/sec) and high resolution (800 dpi) at A3 size printing format resulting in printing at extreme data rate of 440 Mpixel/sec.

To achieve high quality for such challenging requirements, a conventional optical design was uniquely optimized for the use of a 12-beam laser diode array together with a 6-facet high speed (33,000 rpm) polygon scanner. In order to maintain the imaging spot uniformity within sufficient focal depth, we had to achieve high dynamic optical performance (especially flatness) of the polygon system as well as to keep under stringent control the surface shape quality and adjustment accuracy of the scanning optics.

The printed image quality depends very much on color plane registration between separations, as well as on local placement accuracy of image lines in the process direction within each color separation. The free running polygon that is not synchronized with the process direction movement, is able to introduce color registration errors up to half of a 12-line scan (187.5 μm). Such a big error is not acceptable and should be corrected. Writing an image at a constant scanning speed while the machine process speed is inevitably instable may result in severe banding artifacts on the printed image. Solution for both problems is given by using a controlled high bandwidth Dynamic optical system that places the image lines at correct equidistant positions detected by a rotary encoder attached to the PIP drum (ITT).

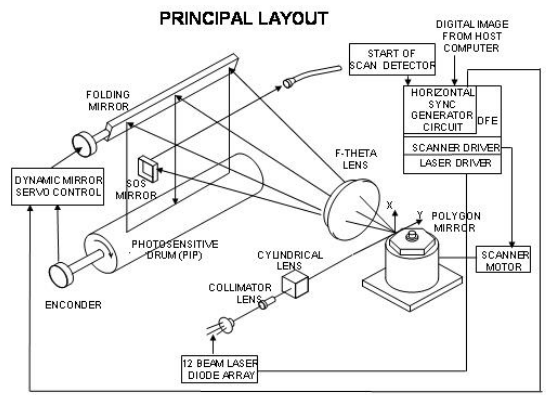

Figure 1. Principal layout

Introduction

The vast majority of optical scanners (Writing Heads) for digital printing utilize F-θ lens scanned by polygon mirror scanning technology. Such systems proved to be comparatively cheap and reliable. With the continuous move of the market to higher printing speeds and print quality especially required in commercial and industrial digital printing, there is a need to develop Writing Head technologies to support that. Most of the existing digital printing engines use a multi-station configuration in which each such station prints one color. In case of using 4 process colors the actual printing speed is defined as the single process speed divided by four, since all four color stations are printing in parallel. HP-Indigo printing presses are unique in a way that they are using a color switching technology that enables us to have only one process station for as many color separations as needed (usually up to seven colors). In order to maintain printing productivity in HP-Indigo press configuration the process speed should be increased proportionally to the number of colors required to be printed. The Writing Head as major part of the process should meet this requirement as well.

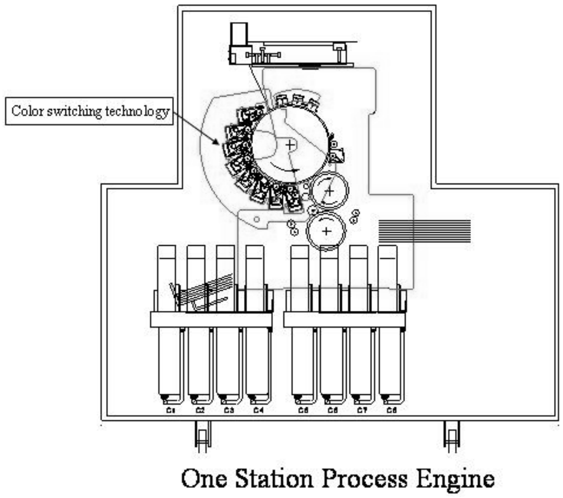

Figure 2. Machine configuration

Laser Scanning Unit Requirements and Optimizations

The Writing Head basic system is built of a laser light source, collimator optics, multi-facet polygon scanner and anamorphic F-θ lens optical system.

System specification:
- Format width - A3
- Process speed – 1.2 m/sec
- Optical resolution – 813dpi
- Pixel rate – 400 Mpixel/sec

There are different constraints that limit the possibility of simple system design such as:
- The polygon speed versus size trade off is one of the major obstacles
- The laser source power and its driving speed limitations.

Polygon

The scanning speed of the laser scanner basically depends upon number of beams operating simultaneously, number of polygon facets, and polygon rotation speed. The right understanding of polygon performance at high rotation speed is critical for implementation of higher throughput and print quality products.

There are several technological problems associated with development of high speed polygons, while probably the most serious problem is related to polygon facet flatness. On one hand, the facets flatness specification is needed to be tightened when moving to higher print quality that inherently requires higher optical resolution. On the other hand, at high rotation speeds the polygon is subjected to strong centrifugal forces capable to influence the initial (static) facets flatness. The amount of this dynamic distortion of the facets quickly increases with rotation speed ($\propto\omega^2$) imposing the main quality limitation for high speeds. This distortion strongly depends on the polygon disk material, polygon disk size and shape, attachment method of the disk to the motor axis, etc.

One of the main conditions for high quality (banding-free) digital printing is that the light spot size variation for all system parameters (and especially between different facets of polygon) is small enough. The max spot size variation value of 10% could be taken as the most optimistic estimate for this limitation. Under this condition a quite generic banding-free requirement for flatness variations between different facets of the polygon is:

$$(\delta_{facet})_{p\text{-}p} << \lambda/7 \qquad (1)$$

where δ_{facet} is the sag value of facet deformation on the footstep of the beam on the facet. In HP-Indigo system this footstep size is about 15mm that is 40% of the full facet size. At the polygon speed of 33,000 rpm the dynamic deformation of facets of the polygon like ours (Aluminum, ∅65mm) may be in the range of $\lambda_{HeNe}/3$ to λ_{HeNe} strongly depending on the disk-to-shaft attachment method (see example in Fig. 3).

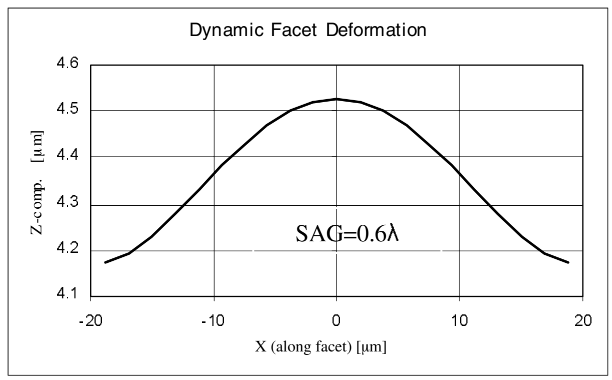

Figure 3. 6 facets Aluminum disk (Ddisk=Ø65mm, d center hole=Ø22mm) at 33,000rpm

Laser Source

The parameters of interest are output power, driving speed, number of beams, wavelength. Uniformity within the multi-beam source (power characteristics, wavefront quality, distance and alignment between the elements) as well as thermal and electrical interaction between the beams is very important.

In order to achieve high spot size uniformity on PIP the imaging system should be optimized for minimal possible curvature of the focal planes. With the multi-beam light source the system becomes essentially off-axis, where the focal planes of different beams are separated (tilted and/or shifted) one from another. As this separation is proportional to the spacing between the beams in the source, that would require to minimize this spacing as much as practically possible. Also it becomes very important to optimize the system optical design for minimal focal plane separation between beams.

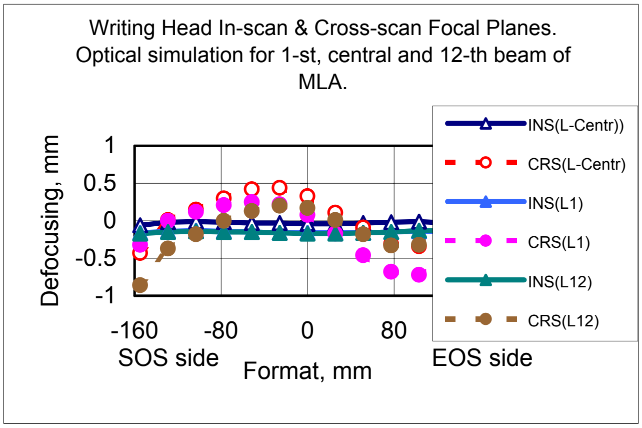

Figure 4. focal planes

Another important feature of multi-beam scanning systems that should be considered in the design is Differential Bow of the scanning lines - different curvature of scanned beams in the direction perpendicular to the main scan plane (see illustration in figure 5). It is essentially caused by the fact that different laser beams scanned by the polygon enter the F-Θ Lens at different angles with respect to the main scan plane. Differential Bow may become significant cause of banding and various artifacts that affect print quality, and hence should be minimized in the optical design of F-Θ Lens.

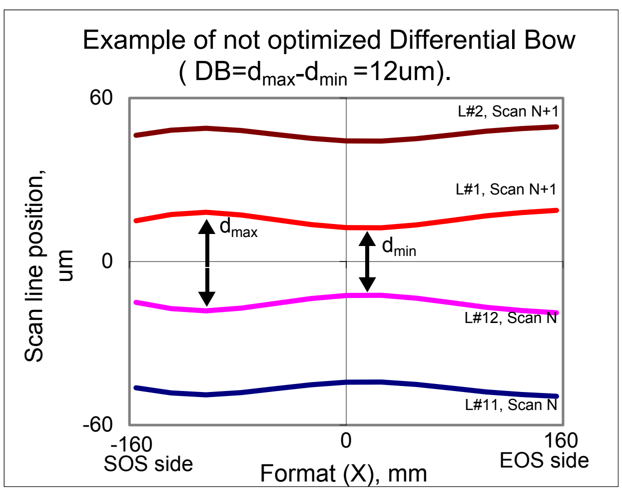

Figure 5. Differential Bow

Problems and Solutions

As a result of the two mentioned above obstacles the solution that uses 12-beam monolithic laser array (MLA) was chosen. Each individual scan resulting from each polygon facet writes 12 horizontal lines (corresponding to 12 laser beams) in parallel.

There are some specific parameters that should be taken care of while using such a system:

1. The MLA should be adjusted at a small rotational angle around the system optical axis with respect to the scanning plane in order to get the correct line spacing in the focal plane of the optical scanner.
2. In order to minimize in-scan scaling variation between beams, the optical system should be accurately corrected for the color aberration caused by the lasers wavelength variation within the MLA.
3. The optical system design should be optimized for the off-axis beams in the way that it will minimize otherwise it results large differential bow between the scan lines of the 12 beams.
4. The optical design should maintain uniformity of spot size and shape between laser beams taking into account the system off-axis configuration, and all that within sufficient focal depth along whole printing format.
5. The control electronics should compensate for the beam skew (different in-scan image positioning of each beam) by introducing different electronic delay to the data stream of each beam.
6. The MLA should be designed and produced with identical spacing, low thermal and electrical cross talk between the different 12 beams.
7. The output power of the scanning system should be controlled in the way to achieve high uniformity between beams, polygon facets, and along printing format width.

The Need for Image Tracking System (ITT)

One of the difficulties to achieve high digital print quality relates to the possibility to write uniform image on the photo imaging plate (PIP). Accurate placement of the image on the PIP within and between color separations defines the image quality level. Any non-uniformity caused by one of these two parameters results in a printing quality problem called Banding and/or Color Plane Registration.

There are two basic ways to control the image placement:

1. To keep the relative speed between the scanning polygon and the PIP drum constant and accurate
2. To monitor both systems speed and use an interim system that can compensate for the relative speed instability by tracking the position of the PIP with the scanned beam. We call this way ITT (Image Tracking Technology)

The first solution might be very difficult to implement since the printing machine is very heavy with high inertia, and during its operation many different impact loads are applied due to engage/disengage of process stations.

As a result HP-Indigo has chosen the second solution for its machine operation.

ITT System Description - System Description

A laser scanning system writes the image on a rotating PIP drum. The scanned output beam passing through a folding mirror is being controlled by servo control system. There are two sensors in the system. One is the Encoder, the second is Dynamic mirror angular sensor. The encoder is attached to the PIP drum axis and detects the actual position of the drum. The second measures the angular position of the servo controlled dynamic mirror. The internal closed loop servo control system gets the data from the two sensors and calculates the position error between the two systems (scanned beam and PIP drum position). The correction signal is sent to the dynamic mirror torque motor to compensate for the error.

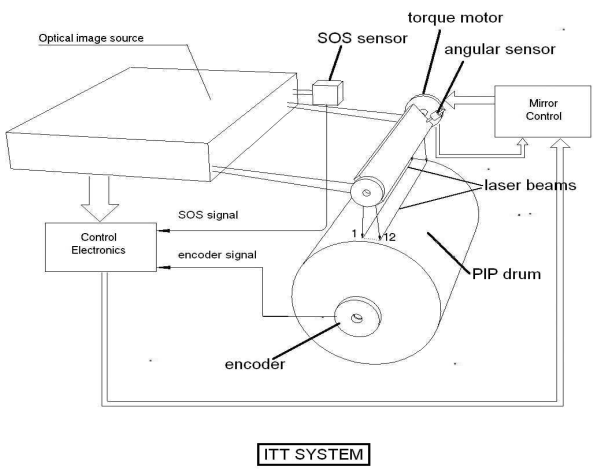

Figure 6.

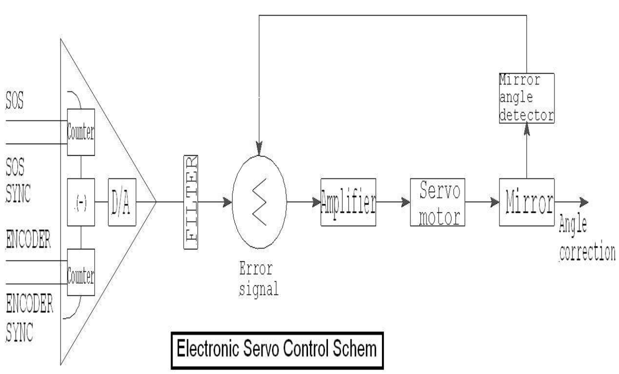

Figure 7.

Conclusions

- High speed, high quality digital printing press with Polygon based imaging writing system requires printing parallelism in order to overcome polygon speed and data speed obstacles. HP-Indigo has chosen the MLA as the solution
- The MLA solution requires to take care of a whole set of new parameters that are not important while using a single beam system.
- In order to minimize non-uniformities on the prints such as Banding and/or color plane registration problems a closed loop servo controlled image tracking system call ITT was introduced into the writing system.
- All of those requirements to new parameters are achievable, but the solution should be very carefully optimized for performance versus price.
- Our resulting writing system was found to be of high quality.

Biographies

Haim Livne Electro-Optic Engineer, worked for 6 years in developing Imaging systems for the Israeli Army. For six years he worked in developing a visual guiding system for Arc Welding Robot. Two additional years as founder of a company to implement thermal Imaging systems for civilian's applications. Since 1988 he has been working in Indigo and HP-Indigo, managing the development of laser based writing systems for digital printing presses as well as being responsible for Indigo product print quality Forum. He holds several patents.

Michael Plotkin received his M.Sc. Degree in Physics from Moscow Institute of Physics & Technology. Since 1980 to 1990 worked as research scientist in P.N.Lebedev's Physical Institute of USSR Academy of Sciences (Moscow) and in the Institute of Atmospheric Physics of USSR Academy of Sciences (Moscow). Since 1991 has been working for Indigo Ltd. (now HP, Indigo Division) in the field of electro-optics and laser scanning. He played active role in development of two generations of scanning systems for Indigo digital offset presses, holds several patents in this field.