High Speed and High Definition Technology for Laser Printing

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Abstract

A new type of multi-beam laser scanning unit was developed that makes high speed and high resolution printing possible. The system simultaneously scans adjacent scanning lines by combining beams from two laser diodes (LDs).

Features of the unit are as follows:

1) Easy to operate because the light sources and all functions related to beam combination are unified in a light source unit.
2) Easy setting and changing scanning line pitch using a simple mechanism.
3) Adaptability to all standard LDs. The optimum LD for the optical system can be chosen.
4) Can be upgraded from a single beam scanning unit simply only by replacing the light source unit.

This paper shows the structure and features and describes how implementation of this new type of multi-beam laser scanning unit [1] (outline shown in Figure 1) was achieved. This multi-beam laser scanning unit is installed in Ricoh MFPs and digital copiers.

Introduction

Because of large volume document circulation associated with the rapid spread of the Internet and multimedia, year by year, high speed and high definition document printing is becoming increasingly important in various circumstances from home to office.

Digital copiers and laser printers, prevalent because they achieve high speed and high quality images, record an image by scanning the beam of LD onto a photoconductive drum using a high speed rotating polygonal mirror and an optical system.

A subject here is how to rapidly scan a laser beam to record a high definition image at high speed. There are two main approaches taken to solve this subject.

The first method uses a high speed driving motor for polygonal mirror rotation. The scanning speed increases with the motor rotation speed. However, it is difficult to greatly improve scanning speed by this method, because with increasing motor rotation speed causes various problems including heating, vibration, noise, reliability reduction and increasing cost.

The second method uses multiple beams. By simultaneously scanning multiple lines using multiple beams, it becomes possible to record at a speed the number of beams times faster without increasing the speed of the driving motor for polygonal mirror rotation. This is the most effective way to increase the printing speed.

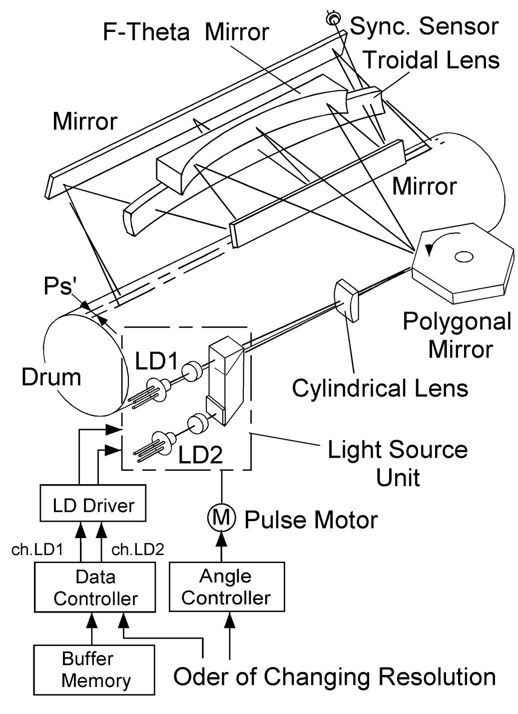

Figure 1. Schematic drawing of multi-beam laser scanning system

Multi-Beam Laser Scanning System

In the second method, the following are two examples of implemented types of scanning units that adjacent scanning lines are scanned using two beams with LDs as emission sources and record the image by direct modulation of the LDs.

One method uses a single monolithic two-channel LD array and the other uses combined beams from two separate LDs.

LD Array System

In a two-channel LD array, two points of emission are monolithically formed in close proximity on the same base. They can emit laser light independently. The scanning performance of scanning units using LD array as light sources is stable.[2] However, the LD array itself is not in demand for applications other than laser printing, so production amounts are small and the choices are also limited depending on the manufacturer.

Beam Combining System

The method combining the beams of two LDs mainly uses a polarizing beam splitter to combine the beams. The beams of two LDs are incident on a polarizing beam splitter from mutually orthogonal directions, superimposed on the optical axis of the optical system and emitted. Then, by offsetting the beam incidence position or the angle of incidence onto the optical system by a minute amount in the sub scanning direction, scanning lines are recorded on the photoconductive drum with a specific pitch.

The advantage of this system is that it can be implemented using two independent light source units with the same structure as for ordinary single beam scanning units, so the power and wavelength of the LD can be freely chosen. However, the scanning line pitch changes with slight variation in the conditions of beam incidence onto the optical system, so there is also the problem of how to precisely set and maintain the stability of the sub scanning line pitch.

To solve this problem, laser scanning units implemented so far detect the beam location using a divided photo detector. Types that compensate the beam location using a servomechanism with a galvano-mirror that deflects the light beam angle in the sub scanning direction based on the detection result are reported.[3]

New Light Source Unit for Beam Combining System

This paper describes a two-beam application of the new type of multi-beam scanning unit we developed.

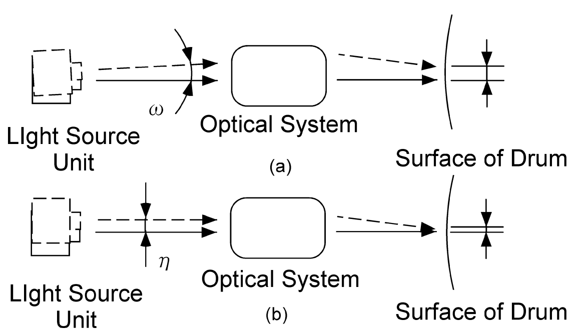

Figure 2. Characteristics of optical system with beam (a) angular and (b) parallel displacement

Scanning Line Pitch Stabilization

The following are the calculation results for the amount of angular and parallel displacement of the beam with respect to the axis of the optical system, when a 10μm displacement, of the beam spot location on the surface of the photoconductive drum in the sub scanning direction, occurs.

Beam angular displacement ω	*0.006 degrees*
Beam parallel displacement η	*0.18 mm*

When the beam is displaced in a direction parallel to the optical axis, the change in the sub scanning beam spot location is relatively small because of the optical conjugated relationship. In contrast, when the angle of the beam is shifted, there is a large change in the sub scanning beam spot location. It is also apparent from the results that variation of beam spot location is made with a slight tilt owing to minute deformations of the scanning unit housing. These characteristics of optical system are explained in Figure 2.

Moreover the structure of the laser scanning unit becomes complicated. Because parts added to combine beams and to adjust scanning line pitch become sensitive to the deformation of laser scanning unit housing. So it is also easy to cause displacement of beam spot location.

Therefore, scanning line pitch adjustment is difficult to maintain, with respect to environment variations in beam combining systems using two independent light source units.

The measured results of scanning line pitch displacement owing to temperature change are shown in Figure 3. A scanning line pitch displacement of 100μm or more occurs in the case of a conventional system that does not use a servomechanism. To obtain enough image quality, it is desirable to control the displacement to 10μm or less.

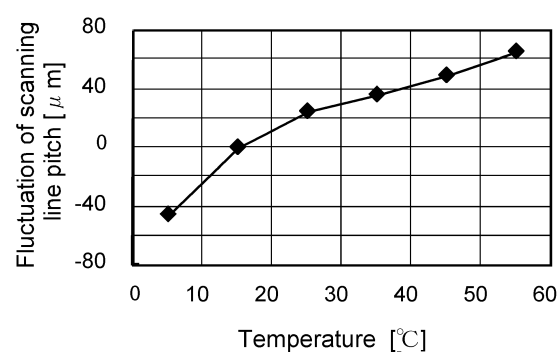

Figure 3. Dependence of fluctuation of scanning line pitch on temperature (conventional system without servomechanism)

We thought it possible to stabilize the scanning line pitch, even without a servomechanism, by modularizing the whole system as a light source unit, combining LD beams, and removing most factors that cause fluctuation of the angle of the light beam.

LDs and Collimator Lenses on the Same Base to Ensure Coincidence in the Emission Direction

Figure 4 is an assembly drawing of the light source unit for the laser scanning unit based on the above concept.

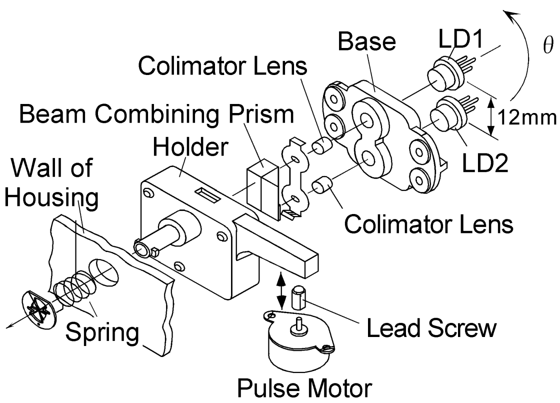

Figure 4. Assembly drawing of the light source unit

The first point is, to stabilize the scanning line pitch, a pair of LDs and collimator lenses are mounted approximately 12mm apart on a base roughly coincident with the beam emission direction in the light source unit. With this approach, equality of the spacing between LD and collimator lens is maintained and it is difficult for variation of the emergent angle of the two beams to occur. The angle between the two beams can also be maintained even if housing deformation occurs.

Beam Alignment in the Sub-scanning Direction Using a Parallelogram Prism

Secondly, the two beams are aligned using a prism with parallel reflecting surfaces. It is necessary to reflect the beams at least twice to align the beams into the same emission direction. Since parallel reflecting surfaces are unified as parts of a single prism, parallelism is always maintained even if variations occur in the environment. Precision of the relative angle between the two beams is improved and maintained.

The excellent results shown in Figure 5, of 4μm or less scanning line pitch displacement owing to temperature change, were obtained by using the above structure and without using a servomechanism.

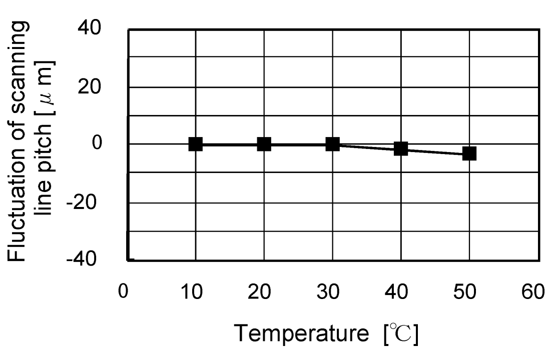

Figure 5. Dependence of fluctuation of scanning line pitch on temperature (new system without servomechanism)

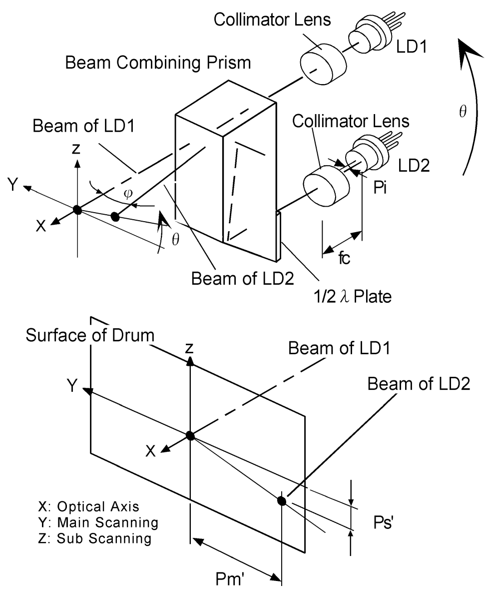

Figure 6. Structure of light source unit

This has decreased the conventional system scanning line pitch displacement to approximately *1/30*, and the desired effectiveness with respect to variation in the environment was confirmed.

Facilitation of Scanning Line Pitch Adjustment

Emitted beams are set with different angles in the main scanning direction.

Reducing the number of parameters and expanding the working range of the adjustment method are necessary to precisely adjust and maintain the stability of the scanning line pitch. Here the third point is that, slight separation of the angle of the two beams produces a beam spot location of several mm in the main scanning direction on the surface of the photoconductive drum.

In this way, scanning line pitch adjustment is made possible simply by constructing a light source unit that can be rotated about the optical axis.

Structure of Light Source Unit

The scanning line pitch set-up is explained using Figure 6. The beam of LD 2 is emitted in the main scanning direction at a slight angle φ with respect to the beam of LD 1. Angle φ occurs by simply offsetting the light beam from LD 2 and the optical axis of collimator lens 2 by Pi in the main scanning direction.

The relationship between φ and Pi is expressed by the following equation:

$$Pi = fc \times \tan \varphi \qquad (1)$$

Where, fc is the focal length of the collimator lens. If Pm is the main scanning direction (Y) component and Ps is the sub scanning direction (Z) component of Pi, then displacements Pm' and Ps' on the photoconductive drum respectively are expressed as:

$$Pm' = \beta m \times Pm \qquad (2)$$

$$Ps' = \beta s \times Ps \qquad (3)$$

Where, βm and βs are the lateral magnifications of the optical system in the main scanning and the sub scanning respectively. In this optical system, if the beam spot spacing on the surface of the photoconductive drum Pm' = 2mm then, Pi becomes approximately 10µm.

When the light source unit is rotated about the optical axis by a minute angle θ, the sub scanning line pitch Ps' on the surface of the photoconductive drum becomes as expressed in the following formula:

$$Ps' = \beta s \times Ps = \beta s \times Pi \times \sin\theta \cong \gamma \times \theta \qquad (4)$$

Where, γ,which is equal to βs × Pi, is a constant so the angle of rotation θ and scanning line pitch Ps', are proportionally related.

This way, the desired scanning line pitch can be obtained by changing the rotation angle of light source unit θ to yield the appropriate scanning line pitch size. In this optical system, if the sub scanning line pitch Ps' is 63.5µm, θ becomes approximately 3.6degrees.

Adjusting Scanning Line Pitch

As shown in Figure 4, the light source unit is held against the optical axis direction datum surface, formed in the housing of the scanning unit with a spring, is subjected to a turning force about the optical axis. A linear actuator that is driven by a pulse motor, arranged in opposition to the turning force about the optical axis, adjusts the light source unit angle of rotation θ to set the scanning line pitch value Ps'. The setting resolution is 0.18µm of scanning line pitch variation per a pulse owing to the combination of pulse motor and lead screw.

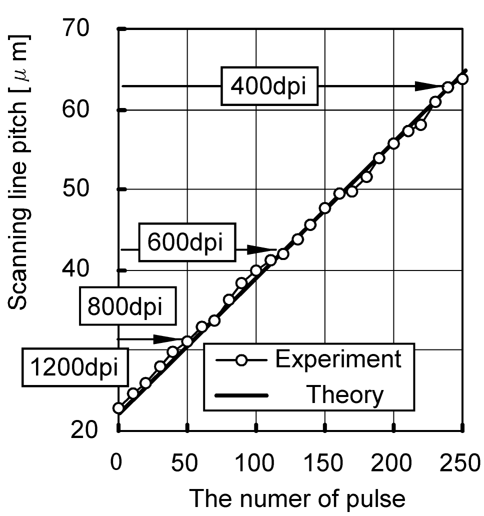

Figure 7. Relationship between number of pulse and scanning line pitch

Performance of Laser Scanning System

We experimentally rotated the light source unit using our variable scanning line pitch mechanism. As shown in Figure 7, we have obtained the relationship between the number of pulses of the pulse motor and the scanning line pitch. The proportional relationship between θ and Ps', as expressed in formula (4), is obtained for resolution from 400 dpi to 1200 dpi.

Scanning line pitch setting can be set simply and easily, using the above currently developed scanning unit. By this mechanism, resolution can be switched to suit different kind of documents such as fax, printer, copier and other specific applications.

Figure 8 shows the scanning line pitch along the main scanning direction when the beam is scanned on the photoconductive drum using this light source unit. Furthermore to improve performance, the scanning line pitch fluctuation can also be decreased by optimizing the path of the beam in the sub scanning direction, and by setting the offset Pi between the beam from LD 2 and the optical axis of collimator lens 2 in the *sub scanning direction*.

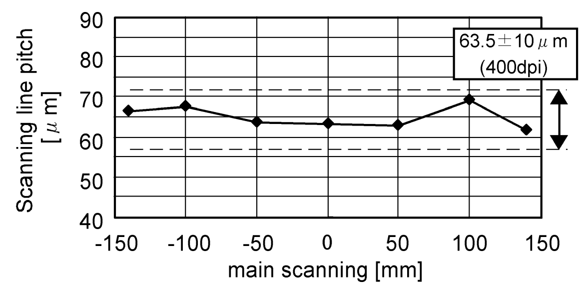

Figure 8. Relationship between main scanning position and scanning line pitch

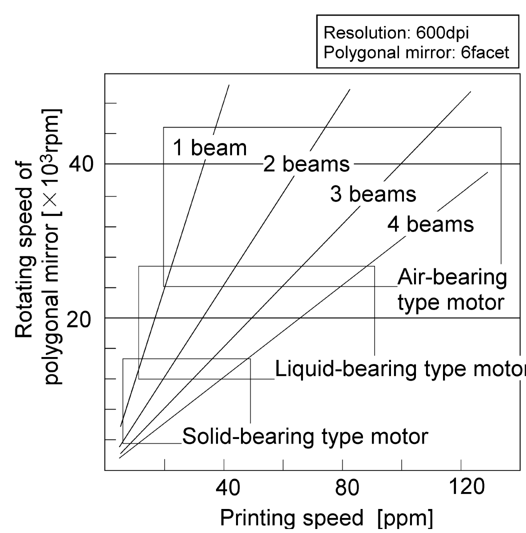

Figure 9. Relationship between printing speed and rotating speed of polygonal mirror

Conclusion

A new type of multi-beam laser scanning unit was developed that effectively restrains angular displacement of the beams and maintains stability without using the servo-mechanism, which is required in conventional beam combining systems, and allows the scanning line pitch to be easily set.

It is clearly apparent that high speed and high definition technology for laser printing using multi-beam laser scanning will become increasingly important in the near future. Under these circumstances, the new technology we have developed is applicable to a wide range of models and specifications. As Figure 9 shows, application development of even larger numbers of beams can be expected.

References

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Biography

Tatsuya Ito received the B.E. and M.E. degrees in mechanical engineering from Keio University, Tokyo, Japan, in 1988 and 1990, respectively. In 1990, he joined Ricoh Co., Ltd., Yokohama, Kanagawa, Japan, where he has been engaged in research and development on optical unit of digital copier and laser printer.

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