High-Speed Laser Printer using Multiple Beams from Optical Fiber Array coupled with Violet Laser Diodes

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Abstract

In high-speed and high-resolution laser printer, parallel recording using multiple laser beams is an essential technique. In the printer we use Selenium photoreceptor which has sensitivity in blue wavelength because it has high-durability. In the optics of our conventional printer the beam from an Argon laser is divided into multiple beams by a grating, and a multi-channel acousto-optic modulator modulates the beams. But the optics has a limitation to raise the print speed because the heat from the air-cooled Argon laser is too large to raise laser power. To overcome it, we have introduced an optical fiber array device coupled with violet laser diodes instead of the Argon laser, and realized high-speed printer of 1400 mm/s with 600 dpi (23.6 dots/mm) successfully.

Introduction

In laser printers of high-speed and high-resolution, the multiple beam scanning is an essential technique because the transfer rate of print data and the rotation speed of the polygonal mirror would be over practical limits if one beam scanning were adopted.[1,2] In the printer we use a Selenium photoreceptor because it is durable and has long life in printing. As the photoreceptor has sensitivity in blue wavelength region, in our printer Argon laser of the 488 nm wavelength is used. But much heat produced by the air-cooled Argon laser makes it difficult to raise the laser power and print-speed even more. From this situation, we have developed the laser printer optics using an optical fiber array device coupled with violet laser diodes of the 405 nm wavelength that have been recently developed. As the result, we have demonstrated high-speed printer of 1400 mm/s with 600 dpi (23.6 dots/mm) successfully.

Specification of Scanning Optics

The rotation speed of a polygonal mirror and the time duration to print one dot are calculated for one-beam scanning case in Fig. 1. If they have to be below 40 k-rpm and 10 ns respectively, five-beam scanning would be required for a print speed of 1400 mm/s, a print dot density of 600 dpi and a print width of 495.3 mm (19.5 inch).

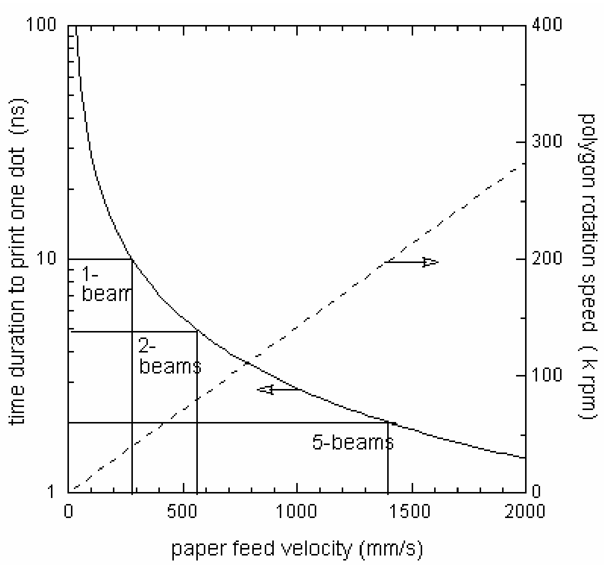


Figure 1. Specification of a laser printer in the case of one beam scanning where the focal length of scanning lens is 510 mm, the number of mirror facets 10, the print dot density 600 dpi and the print width 495.3 mm (19.5 inch).

Laser Printer Optics Using Optical Fiber Array

The laser printer optics using the optical fiber array device is shown in Fig. 2. The optical fiber array device is composed of five LD-modules (laser diode is denoted as LD) and an optical fiber array part. The optical fiber array outputs five laser beams of the 150 µm spacing and 4.2 µm spot diameter. The LD wavelengths of the beams are about 405 nm and the maximum wavelength difference among them is set within ±1 nm so that the lateral chromatic aberration of the scanning lens might be small. In the optics the arrayed beams from the optical fiber array device are converted to parallel beams by a collimator lens. Two lenses with a telescopic arrangement expand the beam widths and make the multiple beams to cross at the polygonal mirror so that the mirror size may not become large. A cylindrical lens in front of the polygonal mirror is used for the facet-tilt correction. The multiple beams are simultaneously scanned on the photo-conductor drum by the polygon. In the printer we adopted the slant scanning method of multiple beams where the multiple beams are set at a slant angle to the scanning direction to form consecutive scan lines on the photo-conductor drum.

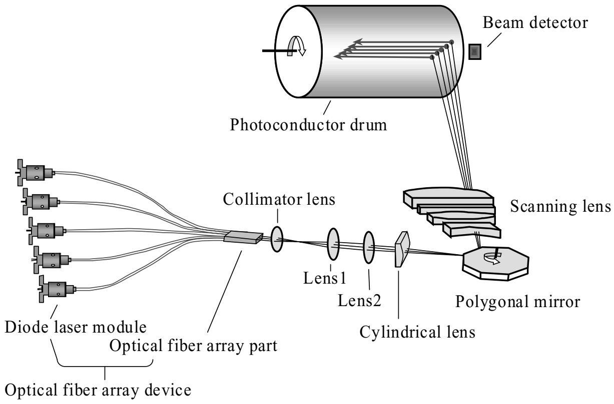


Figure 2. Laser printer optics using optical fiber array device.

The scanning lens has characteristics of the ±1.2 µm/nm lateral chromatic aberration for one-nm wavelength and the about 60 µm spot size over the total print width of 495.3 mm (19.5 inch).

To realize the optical fiber array device we newly developed a single-mode optical fiber for the 405 nm wavelength. The specifications are listed in Table 1. For single-mode operation at such a short wavelength, the core diameter and refractive index difference are set extremely small compared with one for the optical communication field where the infrared light of the 1.3 to 1.6 µm wavelength is used. The LD module is shown in Fig. 3(a). The beam from a diode laser is focused on an optical fiber by an aspheric glass-molded lens. The fiber entrance face is inclined at 8 degree to prevent the reflected light from returning into LD. The throughput efficiency from LD to the optical fiber output was 40%. The photo of optical fiber array part is shown in Fig. 3(b). The optical fibers are arranged with a period of 150 µm on Silicon V-grooves. The vertical alignment error in the optical fiber array causes the pitch irregularities among scan lines and deteriorates the print quality in the slant scanning method. Therefore the alignment error was suppressed sufficiently small.

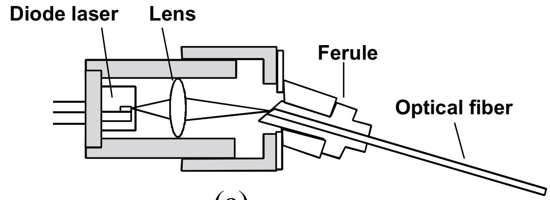
Print experiments were successfully carried out using the optics shown in Fig. 2. The printer is for continuous form paper of a print width of 495.3 mm (19.5 inch), and has a print speed of 1400 mm/s with the 600 dpi print dot density. The photo-conductor drum of Selenium was used. The each violet LD for 30mW was operated at the about 6mW optical power.

Conclusion

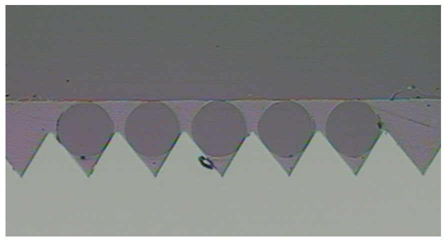
We have developed a high-speed laser printer using the optical fiber array device coupled with violet laser diodes for five-beam scanning. The optical fiber for single-mode operation at the 405 nm wavelength was also newly developed. The mode field diameter was 4.2 µm. In print experiments, we demonstrated a high performance printing with a print speed of 1400 mm/s, a print dot density 600 dpi and a print width 495.3 mm (19.5inch).

Table 1. Specifications of optical fiber for violet laser diode

Wavelength	405 nm
Clad diameter	125 µm
Core diameter	3.7 µm
Refractive index difference	0.15%
Cut-off frequency	380 nm
Mode field diameter	4.2 µm



(a)



(b)

Figure 3. Optical fiber array device: (a) structure of diode laser module, (b) photo of exit face of optical fiber array part.

References

1. K. Kataoka, *Applied Optics*, 36, 6294-6307 (1997).
2. K. Kataoka, *Optical Review*, 8, 218- 226 (2001).

Biography

Keiji Kataoka received his B.S. in 1969 and M.S. in 1971 in Physics from Osaka University, Japan. From 1971 to 1990, he worked at Central Res. Lab. of Hitachi, Ltd., and from 1990 to 2004, at R&D division in Hitachi Koki Co., Ltd. Since 2004 he has worked in the R&D Center in Ricoh Printing Systems, Ltd. His work has primarily focused on the optical systems and optical devices for laser printer. He is a member of the Imaging Society of Japan and the Japan Society of Applied Physics.