Development of 650nm-wavelength-20-channel laser diode array with narrow pitch

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Abstract

Multiple-beam scanning technique is necessary to achieve a high-performance laser printer with high speed and high print resolution. To meet this demand, a laser diode array (LDA), with 20 laser diodes into one chip is developed as the Key Device.

The influences of temperature and stress on the characteristics of the laser diodes are examined, and the reliability enough for laser printer application is confirmed.

Introduction

High-speed printers for business use are widely utilized to print large quantities of data, such as account books, business statements, etc. In addition, recently with the application extended to the printing market of manuals and books, high resolution is becoming an important issue of the laser printers. Increasing scanning laser beams is an effective way to achieve high speed and high quality print.

The LDA has been recognized as a useful device for producing multiple beams, and a four-beam device of the 780nm wavelength is already delivered in the market. [1] But for realizing higher performance printer the number of beams and the wavelength are now insufficient, and we aimed the development an LDA of 20 laser elements, a wavelength of 650nm, and all laser elements are arranged on one chip with a size of 1mm. The shorter wavelength 650nm is visible, and so advantageous for setting up optical unit and obtaining small focused spot on the photoreceptor. The subject for the device is the spread of the characteristics of laser elements and temperature rise in operation. To solve these problems we evaluate the heat radiation structure and the stress on the bonded chip, and as a result the LDA with enough reliability for laser printer application is developed.

Configuration of optical scanning system

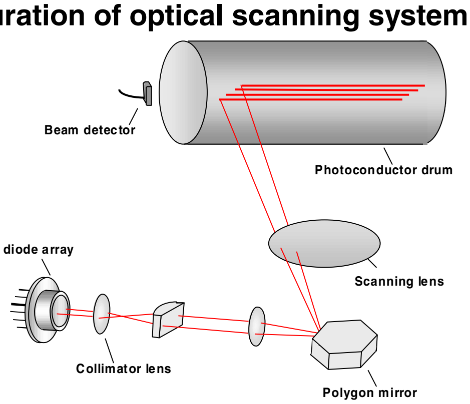

Figure 1. Laser printer optics using multiple beams

Figure 1 shows a schematic diagram of the optical scanning system in a printer using an LDA. The beams are firstly collimated through a collimator lens. Then, through another two pieces of lenses, the beams are expanded and incident at the same position on a facet of the polygon mirror in the scanning direction, and focused in the sub-scanning direction. The beams deflected by the polygon mirror pass through a scanning lens, and scan on the surface of the photoconductor drum. On the drum surface the beams are arranged with a slant angle to form consecutive scan lines. [2]

Requirements to a laser source for multi-beam scanning

In the optical system, the time duration to print one dot is a limit parameter of a laser printer performance. Figure 2 shows the relationship between print dot density and paper feed velocity for the printers in the case of scanning-beam numbers of 5, 20 and 40, respectively, when the time of printing one dot is set as 10ns, the polygon mirror has 6 facets, and the focal length of the scanning lens is 400mm. It can be seem, a 20-beam laser printer has an ability of a print speed of 1000mm/s with a print resolution of 1200dpi. [3]

Therefore we aimed the development of the 20 channels LDA for a high-speed laser printer with a resolution over 1200dpi.

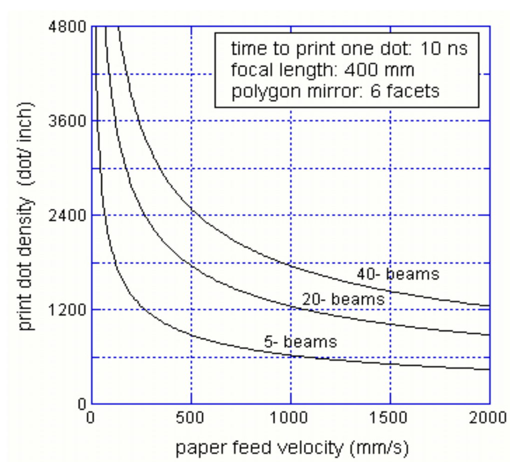

Figure 2. Relation between print speed and print dot density

A light source for a multi-beam scanning optical system should meet the following requirements:

1. Laser power
   The Laser power is related to the sensitivity of photoconductive material, printing speed, and the transmittance of optical system.

2. Spacing between light sources
   As the number of scanning beams increases, the outside beams might receive the influence of optical aberrations. Therefore, the beam pitch of the light-emitting regions should be narrowed.

3. Wavelength variation between the scanning beams
   The wavelength variation between beams causes the difference of scanning width. Considering optical compensation of the chromatic aberration, it is required less than 1nm.

4. Droop and crosstalk
   The driving current of an LD is automatically adjusted on the start of every scanning. On the printing area, the LD is driven by the fixed current. On the other hand, the temperature of the LD rises with the passage of time. The temperature rise in the LD results in a decreased light output, which is called as "Droop" [2], and causes a drop of the print density. The droop rate is defined as shown in Fig 3. In addition, the "Crosstalk" is the phenomenon that the output power of an element in the LDA is affected by turning on/off of the other elements.
   In our case, a droop rate smaller than 10% is required on the condition with all of the LDs emitted.

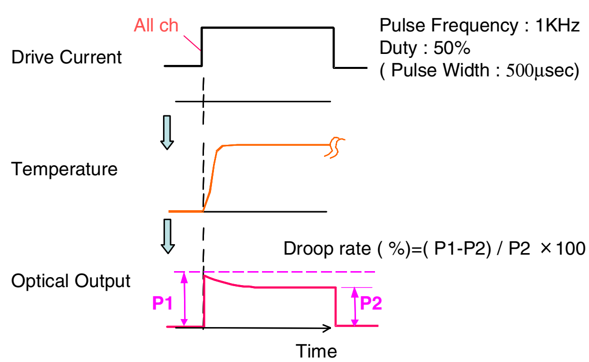

Figure 3. Mechanism of "Droop"

The subjects

Table 1 summarizes the specifications of the 20-channel LDA. Figure 4 shows the subjects to be solved for the device. It is noted that the temperature and stress on the chip affect the LDA characteristics.

The ways to overcome the above listed problems will be discussed in the following sections.

Table 1 Specification

Item	Symbol	Min	Typ	Max	Unit
Optical Output Power	Po	10	-	-	mW
Threshold Current	Ith	10		20	mA
Slope Efficiency	η	0.4		0.7	W/A
Wavelength	λ p		658	660	nm
Droop	Rd	-	-	10	%

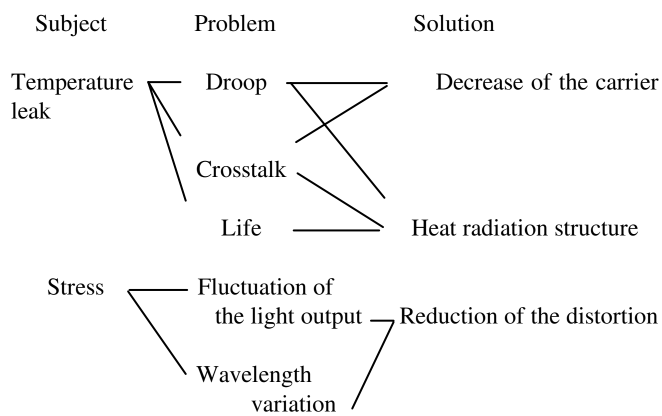

Figure 4. Subjects and Solutions

Solutions for the Subjects

Reduction of temperature rise

Figure 5 shows the schematic structure of our developed LDA chip. The 20 LD elements, having a ridge structure, are equally spaced arranged on one chip with a size of 1mm in the x direction.

The LDA chip is junction-down mounted on a ceramic sub-mount, which is bonded to a heat sink, so that the heat generated by the LDs dissipate effectively.

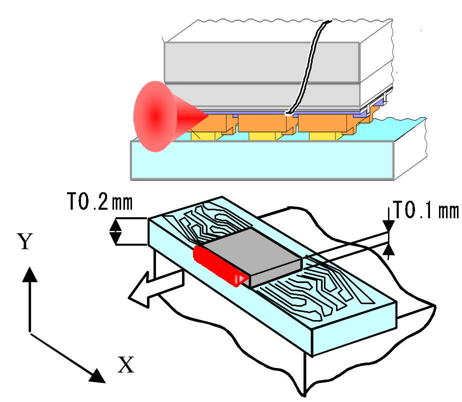

Figure 5. Structure of LDA

There are totally 22 electrode terminals for the LDA (20 for LD channels + 1 for PD + 1 as COM). As shown in Fig 6, a ceramic substrate is used to isolate them from each other. For the conventional package, heat flows out of the device through the heat sink and the package stem. In our case, a protruding heat sink block is used. Therefore, forced air-cooling of the heat sink is possible. And the structure becomes easy to install a cooling fin on the heat sink.

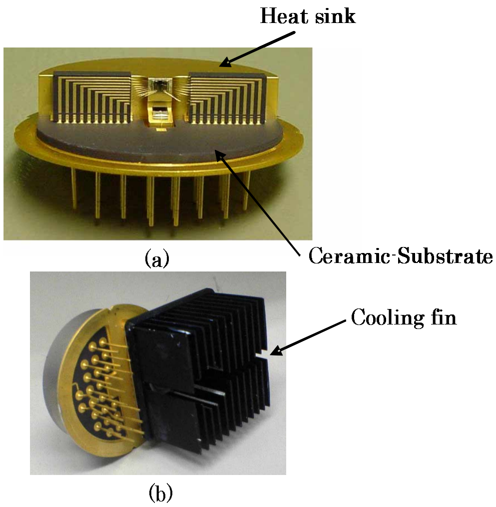

Figure 6. Photograph of inner structure (a) and package (b)

Figure 7 shows the measured package temperature rise versus the operation current where the conventional Φ9mm package and the developed package are used. It indicates that the thermal resistance is reduced from 28°C/W for the Φ9mm package to 17°C/W in our developed package.

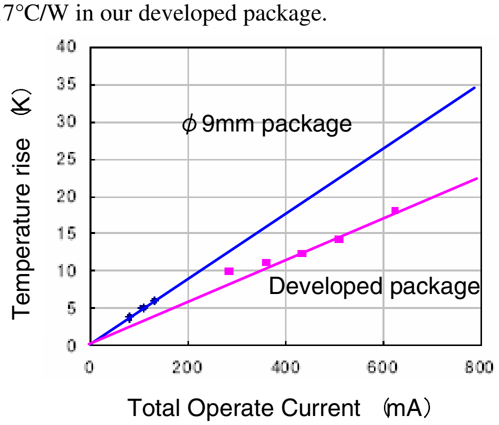

Figure 7. Relation between temperature rise and total current

Reduction of distortion stress

As there are 20 LDs integrated on one small chip, the 20ch LDA is junction-down bonded on a sub-mount to effectively dissipate the heat generated by the LD elements. In some of the LDA chips, isolation grooves are formed between the neighboring LD elements in order to decrease the electronic crosstalk.

Because of the difference in thermal expansion coefficients between the LDA and the sub-mount material, a temperature variation can cause some stress and distortion to the LDA chip. Using the appropriate heat sink material, the distortion of the chip can be suppressed to a very small scale.

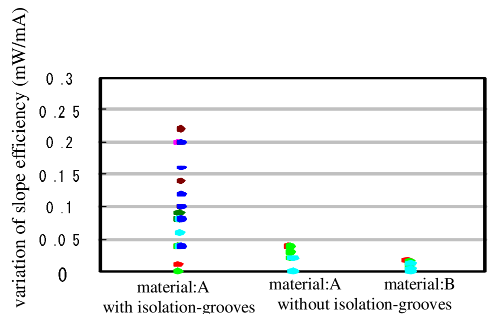

Figure 8. Comparison of slope efficiency variation

Figure 8 presents the tendency of isolation grooves on the slope efficiency of the LDA. It apparently shows that the variation of the slope efficiency of the LDA with isolation grooves is over 0.2 W/A, much larger than those devices without isolation grooves. It is considered to be caused by the different stresses in the devices generated during the bonding processes. Therefore, we adapted the device structure without isolation grooves.

However, without isolation groove between the LD elements, electronic crosstalk may take place. To evaluate the crosstalk effect, an experiment shown in Fig 9 was performed. In the experiment, all of the LD elements of the 20ch LDA are driven at 1kHz, 3mW, and the turn-on time of the elements, ch2~ch20, is 50 microseconds behind that of the element, ch1. A fluctuation less than 2% in the output power of the ch1 rose at the turn-on time of the others. So, the electronic crosstalk has little influence on the print. The small crosstalk effect might be due to the high resistance, which is about several kilo-ohm between the neighboring elements in our sample.

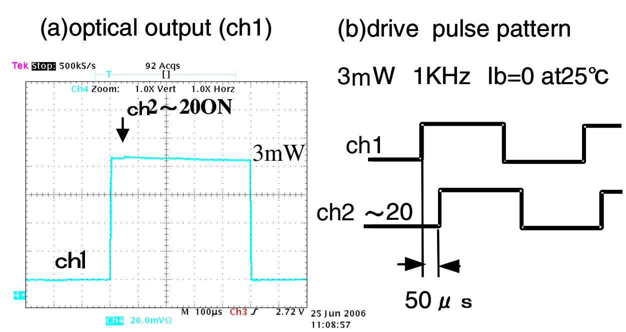

Figure 9. Crosstalk waveform (a) and drive pulse (b)

Reduction of the "Droop"

The carriers and electrons, overflowing from the MQW region to the cladding layer, increase when the temperature rises. These leakage carriers and electrons do not contribute to the stimulated emission. The increased carrier and electron leakage causes a decrease in the laser output power (Droop). The suppression of the carrier and electron leakage was carried out by optimizing the both of the cladding and active layer to reduce the droop rate. The actual effect is shown in Fig 10. One can see that, when all of the elements of the 20ch LDA simultaneously emit with light power of 3mW at 1kHz, the droop rate can be suppressed to less than 10% with a bias current of 0.5Ith at an environment temperature of 60°C. At even higher temperature, the droop rate can be lowered by using a little higher bias current or/and using the above mentioned forced air-cooling method.

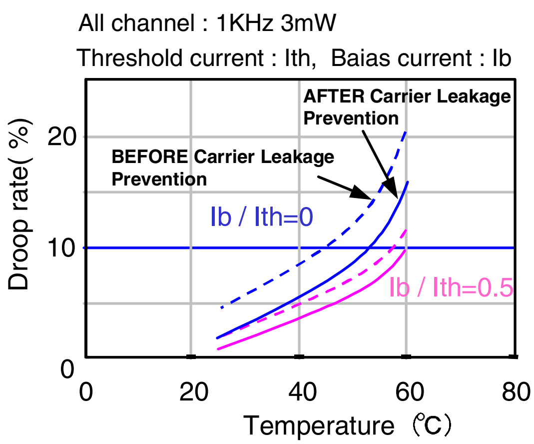

Figure 10. The reduction effect of Carrier leakage

Characteristics of the trial product

Threshold current

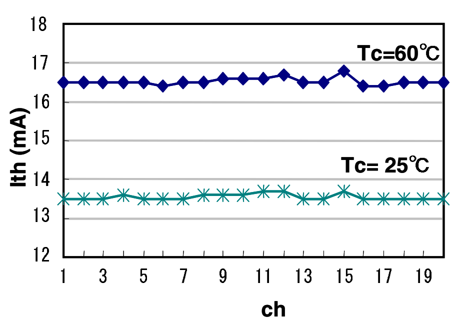

Figure 11. Characteristics of Threshold current

As shown in Fig 11, the threshold current values of the 20 LD elements are around 13.5mA at 25°C, and they are about 16.5mA at 60°C. The threshold current difference between the elements is less than 0.5mA.

Slope efficiency

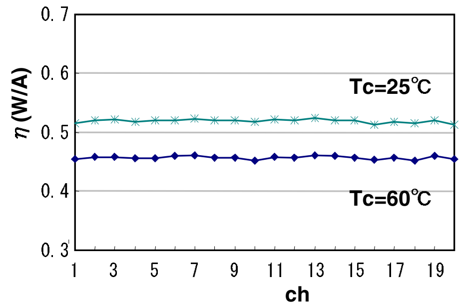

Figure 12. Characteristics of Slope Efficiency

As shown in Fig 12, the slope efficiency of the 20 LDs is around 0.52W/A at 25°C, and the total variation range is less than 0.01W/A.

Emission wavelength

The emission wavelengths of the LD elements are measured. As shown in Fig 13, in a temperature range of 25~60°C, the LDs emit light in the range of 655~664nm. The typical wavelength is about 656.5nm at 25°C.

At 25°C, a total wavelength variation of less than 1nm is available.

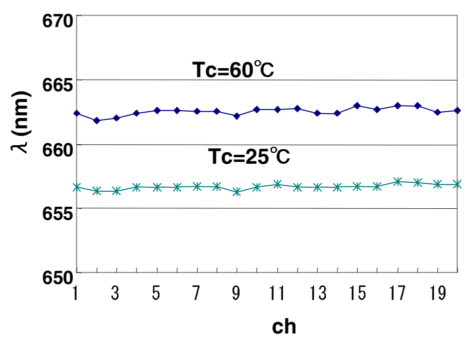

Figure 13. Characteristics of Emission Wavelength

Conclusion

For a high-performance printer with a print speed over 1000mm/s and a print resolution over 1200dpi, the scanning beam number over 20 is required. Subjects for realizing 20ch LDA with narrow pitch are reducing of the temperature rise, distortion stress and droop. These subjects could be solved by the following procedures.

- Reduction of temperature rise was solved by reducing threshold current and installing a cooling fin on the heat sink to cool the chip.
- Reduction of distortion stress to the LDA chip was solved by adapting the structure without isolation grooves and optimization of heat sink material.
- Reduction of the droop was solved by optimizing both cladding layer and active layer.

References

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Industry's First High-Density Integrated Four-Beam Laser Diode for High-Speed LBP and DPPC "SLD262EP"

[2] Junshin Sakamoto, Takeshi Mochizuki, Keiji Kataoka, Development of Multi-Channel Laser Diode Array for High-Speed Laser Printer (in Japanese), Ricoh Technical Report No.32, pg. 75-82. (2006)

[3] Hiroshi Inenaga, Shinichi Nakatsuka, Mitsuyuki Karasawa, Junshin Sakamoto; Application to Printers of Array Laser Diode with a Wavelength of 635nm (in Japanese), Journal of the Imaging Society of Japan, Vol.45, No.2, pg. 15-19. (2006)

Author Biography

Junshin Sakamoto received the B.E. degree from the department of electrical engineering of Saga University, Saga, Japan, in 1980.He has worked as Chief engineer at Ricoh Printing Systems Co., Ltd. in Ibaraki, Japan. His research interests include optical control technology of Laser Beam Printer. He is a member of the Imaging Society of Japan.