Special Edition on System Components

LED Printhead for Use in High-speed, High Image Quality Color Printer

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Abstract

Accompanying the explosive growth in the use of computers, brought on by the recent "Internet boom," and the trend toward more data requiring color, growth in the color printer market has continued at a rapid pace. In offices, data coloration has started and the arrival of color printers with high image quality is keenly awaited.

As one possible solution, there is the tandem-type color electrophotographic printer which uses LED printheads. Comparing this LED tandem printer to a normal laser scanner type printer, the former needs no rotary mechanism, such as a polygon mirror, so it can be smaller and operate faster. However, to achieve color printers with even faster speeds and even better image quality, LED printheads are required which have higher light output and higher resolution. In addition, because tandem-type color LED printers require four printheads, there is a demand for "low cost LED printheads."

In response to this need, we have found a solution by developing a new LED printhead. It incorporates [a] a new type of LED array[1,2] which has a luminescent element characterized by high light output and high density and [b] a matrix-shaped multi-layer wiring configuration.

Here we discuss each characteristic and specification of the LED printhead we developed and the advantages of the new type of LED array which is the key element of the head.

LED printhead

1. The head characteristics which the market demands
   Firstly, there are four characteristics required of an LED printhead to be applied to high-speed/high image quality tandem-type LED color printers: ① high light output, ② low variation in light output, ③ high resolution, and ④high position accuracy of each emitting dot.
   In this section, we show the structure of the new LED printhead and describe its advantages and characteristics, particularly the above-mentioned four items.
2. Head structure
   Figure 1 shows the external appearance of the 1200 dot per inch (dpi) LED printhead we developed. The head consists of LED array chips, driver IC's, and a wiring board, and the printing width corresponds to A4 paper size. Figure 2 shows an enlarged image of the main parts of the 1200dpi LED printhead we developed. By using a new type of 1200dpi LED array, we achieved a wire bonding pitch of 80µm (which is twice that of conventional heads) and reduced the wire bond count to 1/4 that of conventional heads. Moreover, by making a structure in which the LED arrays and driver IC wire bonding pads are removed from one side of the chip, we were able to reduce the number of driver IC's to half that of conventional heads.
   The LED printhead we developed based on this kind of structure has a parts count lower than conventional heads, so mounting becomes easier. Through these improvements, we were able to achieve a printhead that low in cost, compared to conventional heads.

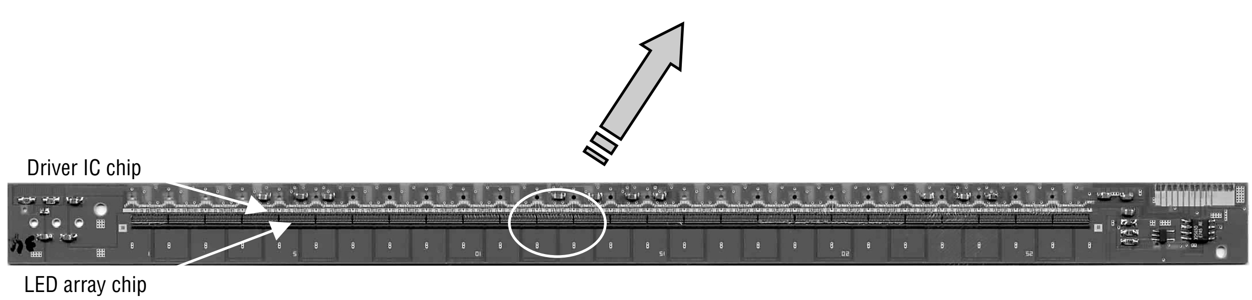

Figure 1: External view of the A4 size 1200dpi LED Printhead we developed.

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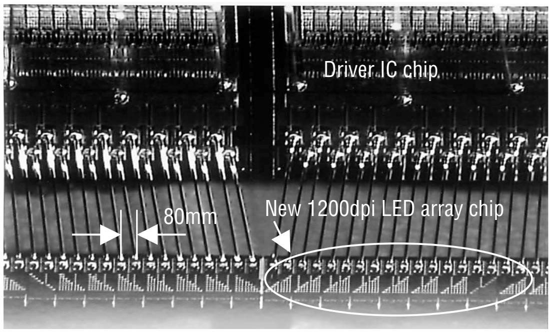

Figure 2: Enlarged photograph of the main parts of the A4 size 1200dpi LED Printhead we developed.

3. Head characteristics...optical characteristics
   Figure 3 shows the distribution of light output after correction, with 1mA of drive current per dot applied. The average light output is 1.1μW/dot which is sufficient for high speed printing at up to a level of 45 pages per minute (PPM). In addition, the head luminescence variation can be corrected to ±1% which is the level necessary for a high image quality color printing.

   Figure 4 shows the distribution of resolution for the entire head. Resolution can be expressed quantitatively as the value of the Modulation Transfer Function (MTF). With this measurement method, every other dot is lighted, the light emitting diameter is measured and MTF is calculated. MTF for the entire head is in the range of 70±10% and even though these are high density (1200dpi) light emitting elements, adequate resolution is achieved.

   Figure 5 is the pattern of luminescent intensity at the focal plane of the lens, in the case when every other dot of the LED of the new printhead is lighted. The luminance pattern of each LED dot is clearly isolated and the MTF value defined in the following equation is approx. 80%. It is clear from the results of these measurements that the resolution is quite high.

$$MTF = (Pmax - Pmin) / (Pmax + Pmin) \times 100\%$$

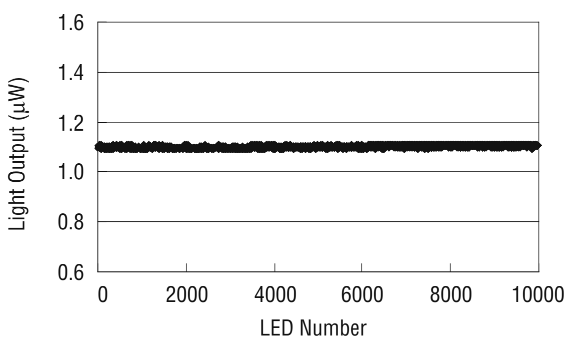

Figure 3: Distribution of head light output after correction

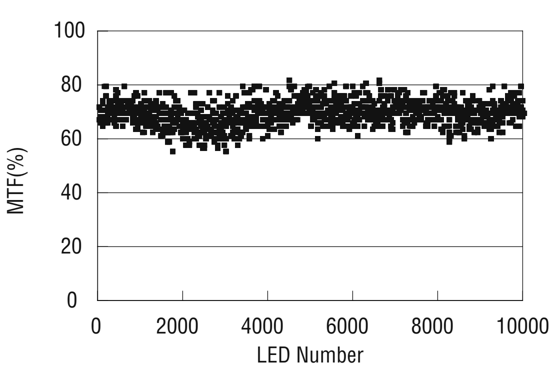

Figure 4: Distribution of resolution across whole head

4. Head characteristics...temperature rise characteristics
   Figure 6 shows the head temperature rise characteristics accompanying operation. Operating conditions are current of 1mA per dot and printing duty-cycle of 10%.

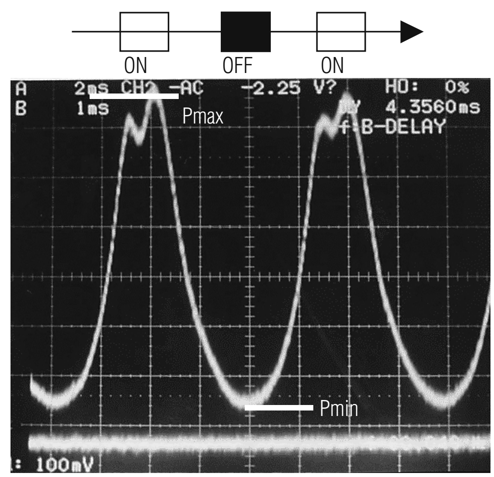

Figure 5: Luminescent intensity pattern at focal plane of lens

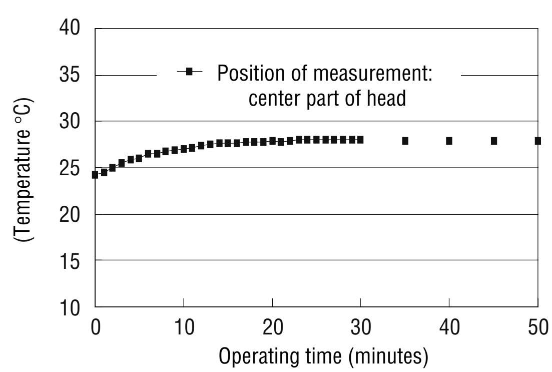

Figure 6: Temperature rise characteristics of head in relation to operating time

Measurements were conducted at normal temperature and the temperature measurement position is the center of the head. From Figure 6, it can be seen that after approximately 30 minutes, head temperature has reached an equilibrium state and the temperature increase is small, at only 5°C. Because this temperature rise is small, elongation of the head due to heat can be minimized. Thus, with little distortion to the image, high image quality printing can be provided. In addition, the maximum electrical current consumption of this head (equivalent to printing solid black on a page) is small at approximately 2A.

5. Head characteristics...position accuracy of emitting dot
For this project, we developed a high precision die bonding technique, enabling us to achieve LED array mounting with high position accuracy. Figure 7 shows an example of the amount of position shift of the emitting dots of each LED array, in both the main (lateral) and secondary (longitudinal) scanning directions, before and after attachment of the rod lens array.

The amount of shift in the lateral scanning direction (X) is the position difference between each emitting dot's actual position and its designed position relative to a reference point. The amount of shift in the longitudinal scanning direction (Y) is the shift of each emitting dot's actual position compared to a reference line. The amount of shift prior to lens array attachment for both the lateral scanning direction and the longitudinal scanning direction is ±6μm or less. On the other hand, even in the state after the lens has been attached, a high "emitting dot position accuracy" of 0 ~ 20μm in the lateral direction and ±20μm in the longitudinal direction is achieved.

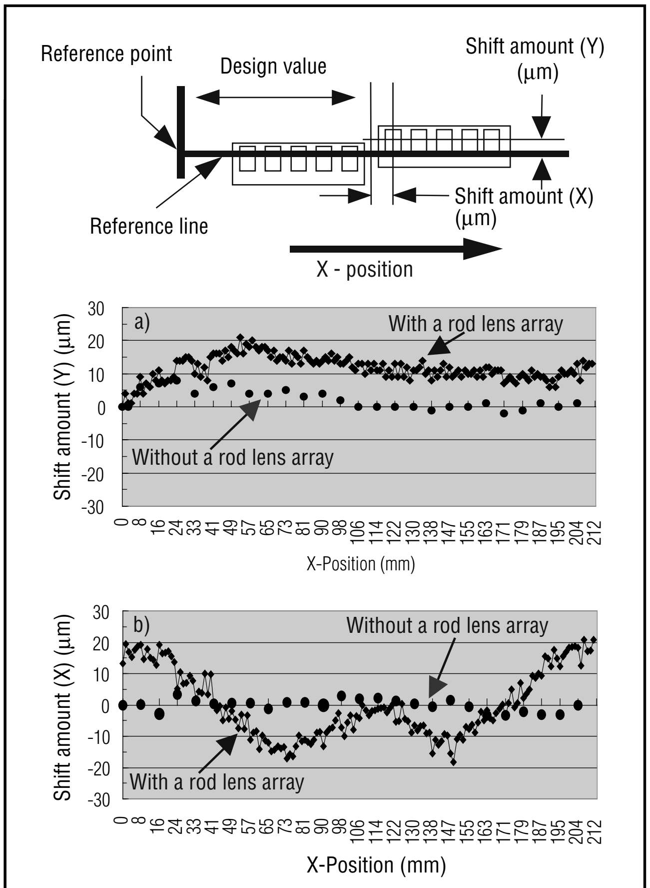

Figure 7: Amount of position shift of emitting dots, with and without a lens array—in the lateral scanning direction (a) and longitudinal scanning direction (b)

6. Head characteristics...head life characteristics
Figure 8 shows the change ratio of average light output of the printhead at each measured time up to 1000 hours of operation, compared to the initial average light output. The operating conditions are: emission duty-cycle of 10%, all dots lighted, and room-temperature atmosphere. As is clear from Figure 8, the change ratio is within 1%. Beyond 1000 hours, Figure 9 shows the change ratio of luminescence compared to initial light output for all emitting dots of the head. No dots show marked change, and the light output change ratio is within ±2%. From the above results we conclude that this head has sufficient life for use as the light source for a color printer.

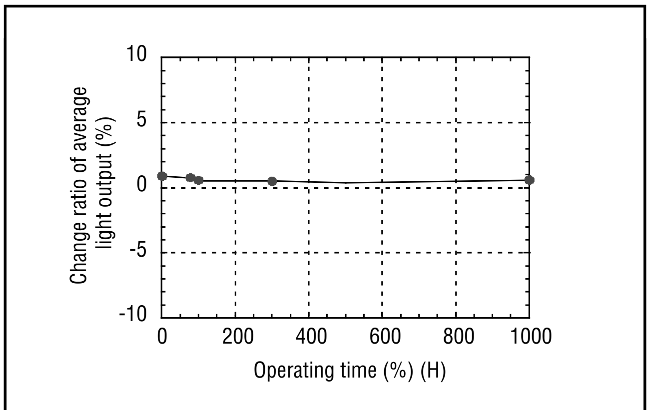

Figure 8: Change in average light output of head

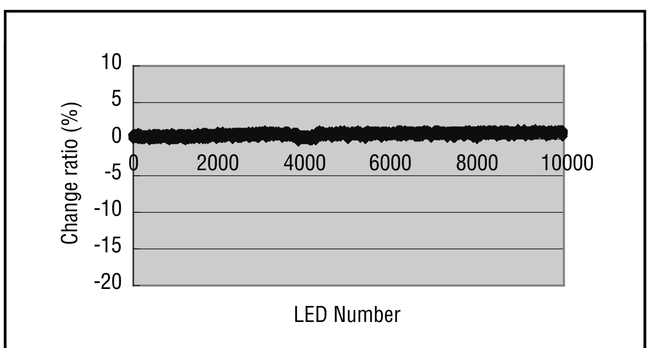

Figure 9: Beyond 1000 hours, the change ratio of luminescence for all emitting dots of the head, compared to initial light output

Item	Specification
Effective printing width	216mm (A4 size)
Total number of dots	9984 dots
Resolution	1200 dpi
Printing speed	45PPM
Emission wavelength	760nm
Average light output	1.1µW(@1mA)
Variation in light output	±1%
Maximum current consumption	2A
Image formation system	Rod lens array with aperture angle of 20°

Table 1: Basic Specifications of the LED printer we developed

7. Head specifications
   Table 1 summarizes the basic specifications of the LED printhead we developed this time. With a dot density of 1200dpi, it can handle print speeds of 45PPM and has the outstanding feature of low current consumption. In addition, we demonstrated that a head with these specifications could be incorporated in a color printer with a slower print speed of 21PPM to obtain a color printer with high image quality.

LED array

1. Structure of the LED array
   The LED array which we developed consisted of LED's, each chip of which had 384 dots. With a 64-dot LED as one unit, each chip was composed of 6 such units ("blocks").
   Figure 10 shows an enlarged photo of one block of the LED array. Each block of it is composed of 8 cells and each cell is formed of an 8-dot LED. In operation, the structure is such that each cell is electrically isolated from the others. By means of a matrix-type wiring structure, discussed below, the structure of the 8-dot LED of each cell has two connection pads in a row—one anode pad and one cathode pad.
2. Matrix-type wiring structure and emitting action
   One anode pad is connected to the 8 LED's of the other cells in one block via an 8 x 8 multi-layer matrix-type wiring. In addition, a cathode is formed for each cell as a "take off" of the cathode pad. As a result, in order to cause, for example, the LED of cell 5 of Figure 10 to emit, in the state that cathode pad 5 is selected, current is provided from the anode pad via the matrix-type wiring. In this way, LED emission in response to data can be obtained.
   By repeating this cathode selection in order 8 times, the emission for one entire block can be done.
3. Basic specifications of the LED array
   Because the LED array we developed is driven by the time division system characteristic of matrix-type wiring, emission times must be made shorter than those of conventional LED arrays. For that reason, to achieve high-speed printing, high light output is necessary.

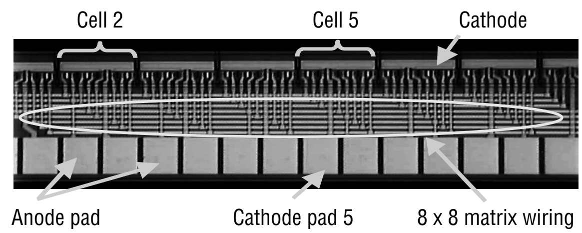

Figure 10: Enlarged photograph of one block of new type LED array

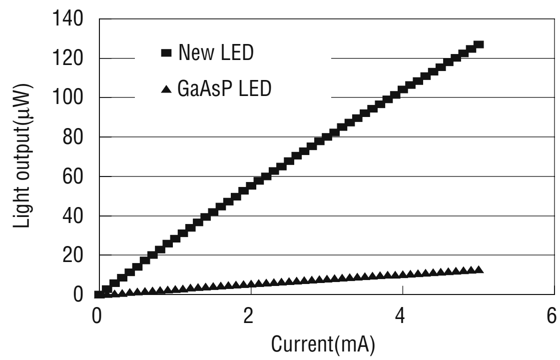

Figure 11: Current vs light output, for new type LED and for 1200dpi GaAsP LED

Figure 11 shows the light output characteristics of the LED we developed and that of a conventional 1200dpi gallium/arsenic/phosphorus (GaAsP) LED. By blending hetero-structure substrate technology and solid phase diffusion technology[3)], we were able to achieve high light output[4,5)] in the light emitting part of the new LED-in fact, 10 times higher than that of a conventional 1200dpi LED. As a result, the LED array we developed can be applied to high speed printing of up to 45PPM with a driving current of just 1mA. In addition, the amount of heat generated in the entire head can be kept to a low level with this LED array because of its high emission efficiency. Thus thermal expansion and contraction do not become a problem in actual printing. In short, this LED array brings together characteristics which enable the realization of superior head designs.

Summary

We developed an LED printhead ideal for high-speed, high image quality printers. This new LED printer head achieves the high performance levels of 45PPM and 1200dpi and has features superior to laser scanner heads. In addition, because the head has few parts to be mounted, the assembly process is easy and the head can be manufactured at a low cost. This combination of attractive features has not been available in one head before.

The new LED printhead, having all three factors of high output, high resolution, and low cost, can be expected to find application not only in color printers, but in copying machines, printing presses, etc.

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