Color Laser Printer Using Four All-in-One Cartridges

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Abstract

A small color laser printer using four all-in-one cartridges has been developed. Four sector-shaped cartridges, each of which contains an OPC drum, a developing unit, a charger and a cleaner, are assembled into a rotary carousel. The carousel rotationally changes each color cartridge to produce primary color images which are superimposed onto an intermediate transfer belt to make a full-color image that is transferred to a paper all at once. This world-first color all-in-one cartridge eliminates hand-dirtying problems during toner and OPC replacement. Furthermore, fewer supply items and a 10,000-page long cartridge ensure less user intervention for the replacing of consumables. Its all-front-access structure which is similar to conventional monochrome lasers affords good user friendliness.

Introduction

Electrophotography is well known for its high speed capability and high quality image production. But, at the same time it requires expensive machine configuration and troublesome maintenance procedures. These are problems for the color laser printers which are prevalent in the market. Meeting customer needs for simple setup and easy operation is a tough challenge with electrophotographic technology. Expensive and insufficient as it may be, the replaceable all-in-one cartridge has been an important lever in fostering the adoption of the monochrome office laser printer because it provides for easy, clean replacement, and improves product reliability. Our development team for developing a compact color laser printer placed the greatest importance on ease of use at the project start point. Finally, we reached a conclusion by developing a color laser printer named the Color Revolver using all-in-one cartridges.

Problems to be Solved For Color Lasers

Troublesome Setup and Maintenance

Laser color electrophotography has been already become prevalent in color copiers. The printing principles of copiers and printers are exactly the same. However, a small-sized copier engine cannot be a printer engine, because the engine of a copier is designed to be supported by professional service staff, while that of a printer should be capable of being maintained by non-professional computer users. Simple setup and ease of use are requirements for color printers. The invention of an all-in-one cartridge has liberated users from hand-dirtying consumable replacement and troublesome maintenance. We thought that in order to avoid hand-dirtying problems and to maintain good reliability, the OPC and the developing unit should not be separated.

Frequent Intervention for Consumable Replacement

The second problem of color lasers is too short an intervention rate (IVR). The IVR shows the number of times a user must replace consumables during 100,000 pages of operation, and represents the average number of pages printed between interventions. For a color laser printer for instance, which has a 6000-page-life OPC and four 6000-page-life developers (6000-page, five consumable items), the resultant IVR becomes;

$$IVR=100000/((100000/6000)*5)$$
$$=1200\ pages. \quad (1)$$

This 1200 page IVR is only half that of a typical low-end monochrome machine that normally has a 2500 to 3000 page IVR. There are two main factors which should be considered in order to extend this IVR.
1) Reduce the number of consumable items.
2) Extend the life of each consumable.

Insufficient OPC Durability

The third problem concerns OPC durability. In conventional four-pass color laser engines, a single OPC drum is employed. At each full-color printing process, the drum is repeatedly used four times, for the yellow, magenta, cyan, and black colors. This means an OPC drum for a color engine should have a durability which is four times longer than that for a monochrome one. This is a heavy burden for a small-sized OPC, and may impair reliability for constant quality color image reproduction.

Mechanical Design of the Color Revolver

Color All-in-One Cartridge

Our answer to the above-mentioned problems is to make a color xerographic engine using all-in-one type cartridges which are similar to monochrome ones. Major merits of using all-in-one cartridges are:

1) Hand-dirtying problems during consumable replacement are eliminated.
2) Widely-used small-size 30 mm OPC can be employed with enough life for keeping good image quality.
3) Consumables items can be reduced from five to four by eliminating the independent OPC unit.

But the question of how four cartridges can be assembled still remains.

Carousel Structure of Four All-In-One Cartridges

Four cartridges can be arranged side by side as a tandem configuration; however, it requires four expensive optical devices, and in addition color registration becomes very severe. Four color cartridges should be arranged in circular formation. Our final conclusion was the Color Revolver, which is shown in figure 1. Four sector-shaped cartridges, each of which includes an OPC drum, a developing unit, a charger and a cleaner, are assembled into a rotary carousel at the center of the machine. Each color cartridge is rotationally changed to produce each color image which is superimposed onto an intermediate transfer belt to make a full-color image that is transferred to the paper at once.

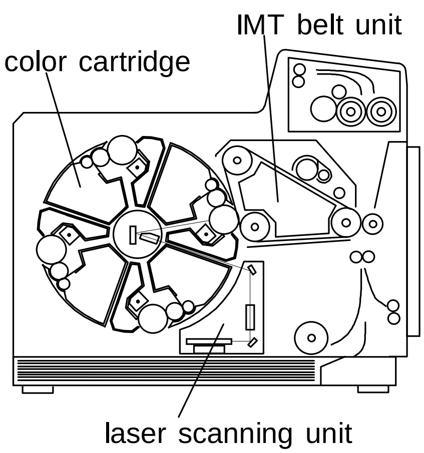

Figure 1. Color Revolver

Elegant Laser Optical Path

There is a big problem to be solved in this design concept of the cartridge carousel. This is how to irradiate an OPC using an optical device. An LED array is small enough to be set at the center of the carousel; however, the optical path length of the LED is so short that the capacity of the toner hopper can not be made large enough. Then this laser optical device had to be newly designed to best fit the arrangement of the Color Revolver. This is shown in figure 2. The newly developed optical device consists of two lenses that are separately arranged in the machine. A laser diode, a polygonal mirror and the first f-theta lens are set outside the carousel, and the second f-theta lens and a mirror are arranged in the center of the carousel. Although the carousel rotates, the second f-theta lens and the mirror do not. Of course, laser light irradiation will not be conducted during carousel rotation. A gap of about 5 mm is created between the two cartridges to allow a laser beam to pass. The beam reflects to the center mirror then enters the cartridge through an exposure aperture in the unit and travels horizontally through an optical path between the toner hopper and the cleaner to arrive at the irradiating station at the left side of the OPC.

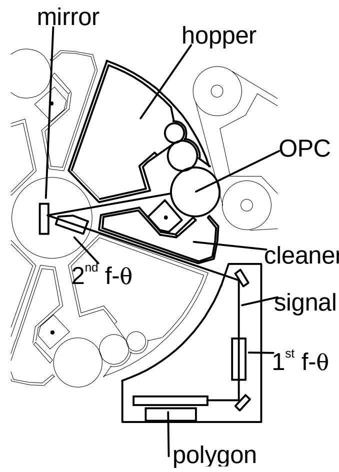

Figure 2. Sector-shaped cartridge and laser optical path

Quality Positioning Technology: QLPT Mechanism

The most difficult problem caused by employing four separate OPC drums is color mis-registration. Each drum has its own mechanical distortion and center eccentricity.

This problem is especially severe for one-pass (tandem) color processes. These mechanical distortions cause printing speed fluctuations, and resultantly color mis-registration in full color images. Misalignment of four colors is caused by the following three factors.

1) Dimensional differences among the four drums.
2) Positioning errors at rotational exchanges of the OPC drum along with the carousel rotation.
3) Fluctuation in angular velocity of the OPC.

The newly developed Quality Positioning Technology (QLPT) mechanism eliminates these image defects and ensures high-quality images. The QLPT mechanism is schematically drawn in figure 3. The QLPT mechanism cancels these misalignment without using finely machined mechanical parts.

1) Precise angular velocity transmission mechanism: Precisely positioning and rigidly unifying grip-coupling mechanism at both sides of the OPC drum ensures the precise angular velocity transmission from the driving mechanism of the main body to each of the four drums.
2) Correction mechanism for center eccentricity of the drum: The OPC drum rotates in constant *angular* velocity, but on the other hand the IMT belt rotates in constant *peripheral* velocity. This difference in speed corrects the elongation/shortening of the image and produces superior color registration.
3) All driving gears for the OPC drum are designed to be in a whole number relationship. Therefore all gears ro-

tate in synchronous phase. This rotation inhibits partial mis-registration.

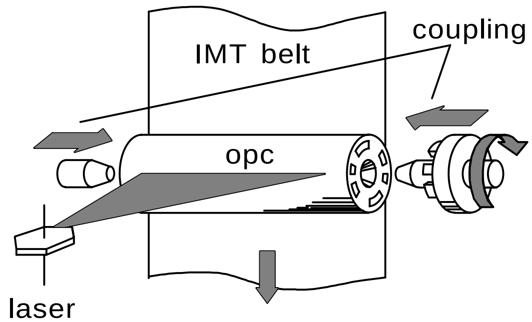

Figure 3. QLPT mechanism

Mono-Component Color Development

The developing station of a color cartridge is shown in figure 4. A toner supply roller, which is made of urethane sponge, charges and supplies toner to a developing roller. The developing roller is made of conductive silicone rubber. The thin toner layer on the roller is regulated by a thin SUS blade. The developing roller contacts directly with the OPC, and creates sharp and high resolution images without undesirable edge enhancement and airborne toner.

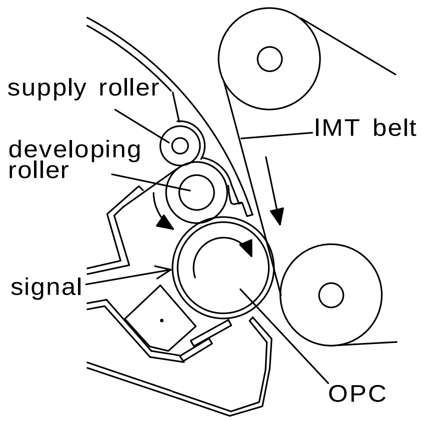

Figure 4. Developing station of a cartridge

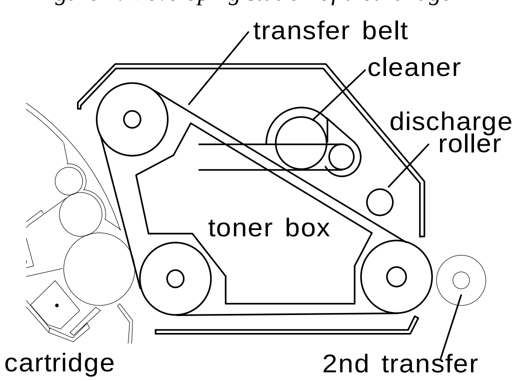

Figure 5. IMT belt unit

Intervention Rate of the Color Revolver

The machine's color toner, OPC, cleaner and charger are housed together in each cartridge and are replaced simultaneously. Each cartridge yields 10,000 pages at five percent coverage. The configuration of each color cartridge is designed to be sector-shaped. With a 10,000-page large-capacity cartridge and the discontinuance of the OPC as an independent item, the IVR of the Color Revolver becomes;

$$IVR=100000/((100000/10000)*4) \\ =2500 \text{ pages.} \quad (2)$$

This rate is long enough for a three to four ppm machine. Furthermore, sufficient reliability can be obtained during 10,000-page life for a 30-mm-diam OPC, a small corona charger and a drum cleaner.

Intermediate Transfer (IMT) Belt Unit

There are two major issues to be solved with the IMT belt unit with regard to user friendliness.

1) From the viewpoint of user maintenance, the toner collection box should be omitted. At the second toner transfer from the IMT belt to the paper, non-transferred toner remains on the belt. This toner should be cleaned up prior to the next image processing. An independent toner collection box increases the number of consumables items and hand-dirtying problems.
2) For the easy access in the event of paper jams, a front-side, upward and straight paper path is desirable. In this rational paper path, the belt cleaner should be arranged at a gravitationally upper position on the belt. This inhibits the use of conventionally employed rubber blade cleaners. A new type of cleaner system that is not affected by gravitational force needs to be developed.

The structure of the IMT belt unit is shown in figure 5. For the first requirement, the IMT belt unit includes a cleaner and a toner collection box inside the unit. The toner collection box has enough capacity to hold 100,000 pages of residual toner. The user can replace the IMT belt as an all-in-one unit.

Table 1. Intermediate transfer (IMT) belt unit

Unit configuration		Belt, cleaner, toner collection box
Belt	**Material**	Carbon-dispersed polycarbonate
	Resistivity	10^9 Ωcm
	Loop length	377 mm
	Thickness	150μm
Discharge roller		Grounded SUS roller
Cleaner roller		Anodized aluminum biased with DC voltage
Life		100,000 images

An electrostatic roller cleaner has been developed to address the second issue. Toner remaining on the belt after the second transfer is discharged by a metal discharge roller, and then cleaned by a cleaner roller. The cleaner roller is composed of an anodized aluminum roller and a thin SUS scraper. The cleaner roller is electrically biased and contacts the surface of the belt. Cleaned-up toner is scraped-off by the scraper. Table 1 shows the specifications of the IMT belt unit. Transfer efficiency from the OPC to the belt is about 90%, and from the belt to the paper is also about 90%.

All Front-Access Machine Configuration

The IMT belt and four color cartridges are separately exchangeable. The engine's four cartridges are housed in a rotating carousel and can be pulled up and down from the top cover as shown in figure 6.

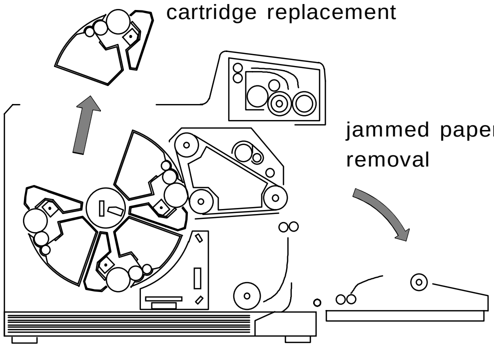

Figure 6. User maintenance of the Color Revolver

The IMT belt unit can be accessed from the front cover. And also in the event of paper jams, the jammed paper can be removed from the front cover. Therefore all maintenance procedures and consumable replacement can be performed from the front side of the machine. The overall structure and appearance of the Color Revolver thus becomes very similar to that of conventional monochrome lasers. The employment of the IMT belt and simple upward straight paper path allow the use of small-sized hard/rigid paper such as postcards or envelopes. Specifications of the Color Revolver are shown in table 2.

Table 2. Specifications of the Color Revolver

Printing speed	3 ppm (full color) 16 ppm (monochrome)
Register accuracy	Within 100 µm
Spatial dot addressability	600 dpi
Cartridge capacity	10,000 pages
Lifetime of IMT belt unit	100,000 images
Media size	Up to ledger size Postcard, envelope

Conclusion

A small color laser printer has been developed. The printing engine employs the world's first all-in-one cartridges. This engine is composed of a rotary carousel made with four sector-shaped cartridges and an IMT belt unit. The lenses of the laser optical device are separately located in the machine, one is at the center and another is outside the carousel. By using all-in-one cartridges, users can replace consumables without hand-dirtying problems. This makes the color machine maintenance-free in the same way as monochrome ones. In addition, the frequency of consumable replacement (user intervention rate) decreases by 1/2 compared to conventional color lasers by (1) eliminating the separate OPC drum, and by (2) employing large-capacity 10,000-page cartridges. Furthermore, a reliable upward straight paper path and all-front access to the machine for consumable replacement and in the event of paper jams give the same user friendliness as monochrome lasers.

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Biography

Hajime Yamamoto obtained a BS and MS in Chemistry from Kyoto University and his Doctorate in Physics from Tokyo Institute of Technology. He joined Matsushita Electric Industrial Co., Ltd. in 1981, where he has been working on the fundamentals of xerography ever since. He has invented a Magnefine Process, a One Drum Color Superimposing Process, and Magnetic Cascade Development.

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