Development of Rewritable Laser System

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Abstract

Various systems for rewritable recording technology have been proposed from the viewpoint of convenience and reducing environmental impact. However, such systems have limitations. A thermal rewritable recording medium that uses high-contrast leuco dye is not suitable for outdoor use because of rapid photofading. In vector scanning, which is an efficient method for drawing characters with a high power laser, repetition durability tends to be degraded by overheating at the crossing and turning points of character strokes. We solved these two problems to permit outdoor application under severe conditions by using novel technologies. The system is a rewritable recording technology suitable for use in physical distribution systems.

Introduction

Recently, electronic paper has become widely used in electronic books. There are two types of electronic paper, as shown in Figure 1: internal drive (Figure 1a) and external drive (Figure 1b) [1]. The internal drive type consists of a front panel and backplane and can display images or characters on the front panel by applying voltage from the backplane. The internal drive type is used in electronic books. The external drive type displays on a rewritable sheet supplied with energy from an external device such as a printer. The external drive type has been used for point cards and IC cards to display numeric characters. In this paper, we propose a contactless rewritable laser system and an application of the external drive type used with a thermal rewritable recording medium.

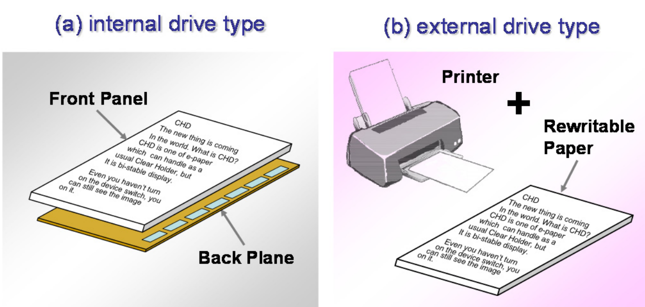


Figure 1. *Two types of electronic paper; (a) internal drive type and (b) external drive type*

Various systems for rewritable recording technology have been proposed from the viewpoint of convenience and reducing environmental impact [2]. Specifically, a thermal rewritable recording medium that uses heat to effect color change was quickly put into practical use and has been widely in applications such as point cards and IC cards to display information such as numeric characters, expiry dates, writing by a thermal print head (TPH) for the recording mode. Applying this rewritable recording technology to industrial applications has been explored for factory automation and physical distribution. In industrial physical-distribution systems, where periodic deliveries are typical, labels with delivery addresses or other content are printed as barcodes or text to ensure proper delivery. For example, these labels are pasted on re-usable tote containers for each delivery. When the tote container returns, the labels are peeled off and discarded, and new thermal labels are pasted.

If these labels, which are discarded each time, were instead made of a rewritable recording medium, the environmental impact could be reduced, resulting in less garbage and lower CO_2 emissions. Furthermore, the expense of pasting and peeling off labels could be reduced and the possibility of physical distribution system problems caused by residual labels could be prevented. Overall, the business's efficiency would be increased by such a system. Additionally, it is difficult for TPHs, which require contact, to print on a medium attached to a tote container that has been deformed, such as by prolonged use. Also, conventional rewritable recording media lacks the photostability needed for use in direct sunlight, such as for outdoor physical distribution applications.

We solved these problems, allowing outdoor application under severe conditions, by using novel technologies such as a newly synthesized material and new laser technology [3][4]. The solution is a rewritable recording technology that is suitable for use in physical distribution.

Basic configuration and features of the system

The rewritable laser system, a contactless laser rewriting system consists of a rewritable laser marker that improves image durability of the medium through the equalization of optical distribution, a rewritable laser medium, and a high-speed rewritable laser eraser (Figure 2).

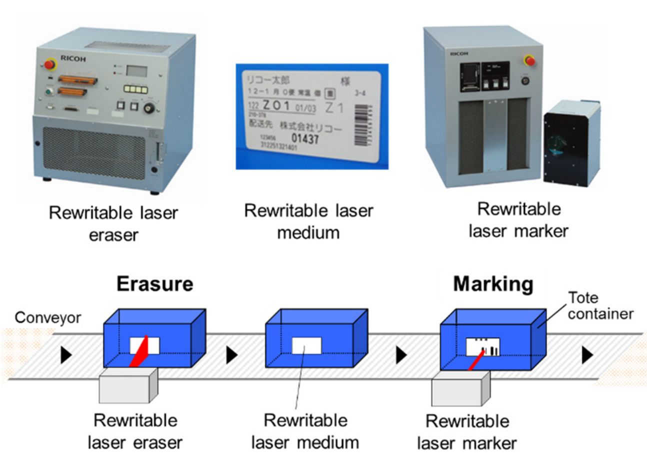


Figure 2. *Rewritable laser system and an example of a contactless rewritable recording medium pasted on tote containers that ride on a conveyor belt*

Device configuration and features of rewritable laser marker

Figure 3 illustrates the optical system for a rewritable laser marker. The laser beam (maximum output 28 W), emitted through fiber optics from the laser diode (LD), forms a circular beam spot that can be controlled by two galvano scanners, which are arranged at 90° to one another through optical lenses. The beam is absorbed by a photothermal material in a recording layer and heats the rewritable laser medium to 180 °C or more and draws a line about 0.25 mm wide on the medium. The galvano scanner changes the laser beam angle, which prints a character using vector scanning, tracing the laser beam as if drawing with a pen.

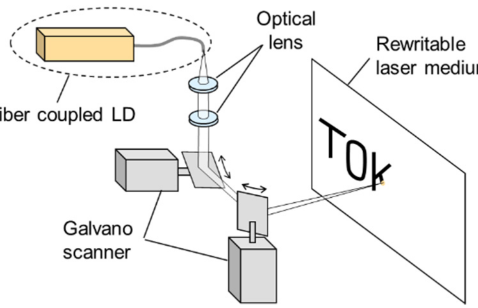


Figure 3. *Basic configuration of rewritable laser marker*

A general laser marker system can print without contact on various materials, such as plastic and metal, and is widely used in production plants to print numbers and dates on products. However, the laser marker's beam has a sharp chevron-shaped optical distribution (Gaussian distribution); when printed on rewritable media, excess heat is irradiated to the central part of the printed areas. One problem with this system is that repeated cycles of printing and erasure deteriorate the medium and result in incomplete erasure.

With the Ricoh laser marker, we can achieve uniform optical distribution of light intensity at both the central and periphery parts (i.e., a tophat beam). This is achieved by the optical system alone. As a result, we can heat the line to print uniformly without irradiating excess energy to the central part of the line. This makes it possible to print at high speed without degrading the medium.

Device configuration and features of rewritable laser eraser

The images on a rewritable laser medium are erased by heating to within 130–170 °C, which is lower than the color-developing temperature. We developed a dedicated eraser to uniformily heat the entire display face to within these temperature limits and at high speed (Figure 4). The laser beam emitted from the LD bar, in which multiple LDs are arranged in a line, is synthesized by a special optical system and irradiated to the medium in the shape of a line controlled by the galvano scanner; images are erased by scanning unidirectionally with the scanner. To erase uniformly, we developed an optical system that combines the beam output from multiple light sources to achieve uniform optical distribution on the entire display face. We also adopted a high-output LD bar (maximum output of 108 W). This enabled fourfold faster erasure compared with a system that scans the entire display face sequentially by using a laser marker.

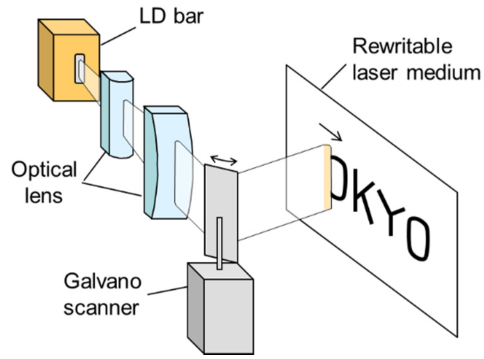


Figure 4. *Basic configuration of rewritable laser eraser*

In addition, we provided an autofocus mechanism on the marker and a mechanism to adjust the beam scanning speed of the eraser. This improves the practicality for physical distribution applications and allows being responsive to container deformation and tote containers of various sizes. Further, we have developed and introduced a unique laser energy control mechanism, which can detecting the medium's temperature, into both the marker and eraser.

Photostability improvement technology for the medium

For physical distribution applications that include exposure to outdoor variations in weather and air temperature, the medium must have high photostability against direct sunlight. The conventional rewritable medium for TPH results in the deterioration of image density, coloring of the base material, and incomplete erasure when exposed to direct sunlight. These results are due to the resolution of the leuco dye in the recording layer by ultraviolet light and oxygen. In recording technology using the laser diode, we form an ultraviolet screening layer above the recording layer (Figure 5). This is done by compounding a new ultraviolet absorber, which intercepts the ultraviolet region below 400 nm and achieves a transmittable visible ray; taking advantage of this feature makes it possible to form a thick layer to transmit a near-infrared laser beam there. Furthermore, the development of rewritable laser medium with high photostability is made possible by forming oxygen insulation layers to block out the oxygen sandwiching the recording layer.

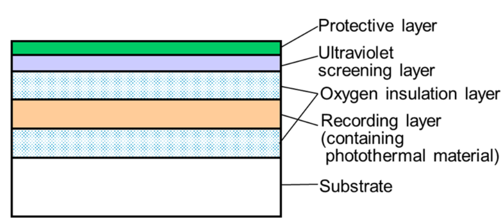


Figure 5. *Basic configuration of rewritable laser medium*

Figure 6 shows examples of the photostability test results with a rewritable laser medium for the new system and a rewritable medium for a TPH system. Figure 7 shows the change in image density and erasure density. The photostability test was conducted as an accelerated test that uses xenon light irradiation; xenon light irradiation for 256 h corresponds to 5 years in an outdoor physical distribution application. As shown in the figure, the image on the rewritable medium for TPH thinned and the base material turned yellow after the photostability test; extreme loss of contrast also occurred. In comparison, the image on the rewritable laser medium showed little change in the image before and after the test. The density measurement result graph in Figure 7 confirms this.

In barcode properties, as well, the rewritable medium for TPH was given a grade of F after the photostability test (i.e., a barcode scanner found it impossible to read); the rewritable laser medium maintained a C grade, which is sufficient for physical distribution applications. Moreover, it can be used in outdoor physical distribution applications for 5 or more years.

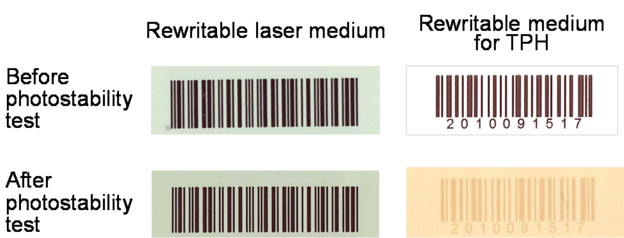


Figure 6. *Photostability test results corresponding to 5 years of rewritable laser media use and rewritable media use for TPH*

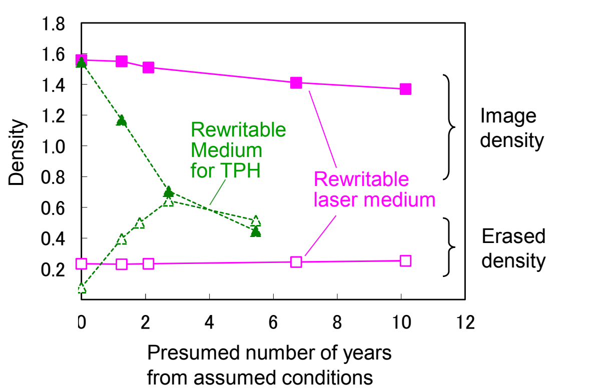


Figure 7. *Change in image density and erasure density from photostability test of a rewritable laser medium and a rewritable medium for TPH*

Repetition durability enhancement technology of medium

A vector scanning printing system that uses the laser marker to trace the beam as if drawing with a pen has the advantage of being able to draw images quickly, compared with a raster scanning system, which writes characters as a set of many dots. The vector format also has the advantage of being able to smoothly express the outline of characters. Because of these advantages, it is widely used for factory automation applications. However, if the character data of a conventional laser marker are used for drawing as-is in a rewritable laser system, intersection and cuff parts are heated multiple times (Figure 8). This adds excess heat to those parts, which may reach the decomposition temperature of the material. When this occurs, the medium is deteriorated, which lowers repetition durability because of incomplete erasure.

If overlapping can be removed, then the excessive heat problem can be solved. Although steps can be taken to create the font beforehand to remove the overlap, as the size and line width of a character change with system setup, a large amount of time and effort is needed to create a font from which the overlapping part is removed in the right proportion. Moreover, in cases in which a font is created by assuming a line width and character size in which there is no overlap, either overlap remains or voids appear, depending on the magnification of the character (Figure 9). As a result, quality falls. To address this problem, we established its laser beam scanning control technology, which can draw high-quality character images without an excessive rise in temperature. This is achieved by developing software to generate character-drawing data in which the overlapping parts of the drawing (which depend on the size and line width) are removed automatically.

By using a rewritable laser marker that incorporates this technology, voids and overlap are prevented, even for characters drawn in a different size (Figure 10). This improves both repetition durability and visibility.

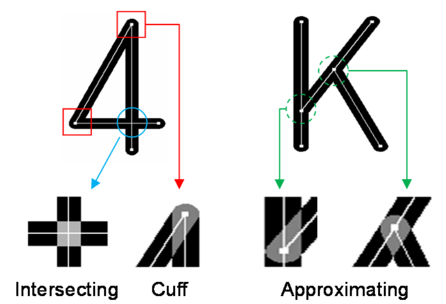


Figure 8. *Example of multiple heatings of intersections and cuffs (turned edge)*

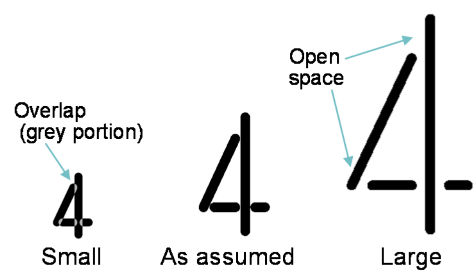


Figure 9*. Example of fonts created; overlap removed and character size changed beforehand*

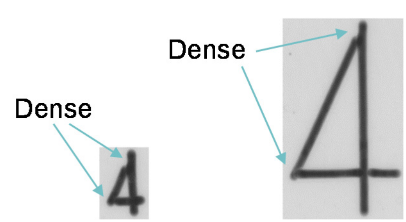
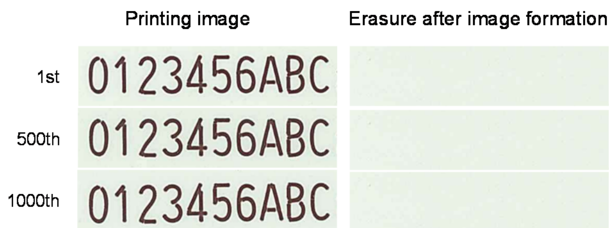


Figure 10. *Image after automatically removing overlap according to character size*

Figure 11a shows the results of 1000 cycles of printing and erasing on a rewritable laser medium. Printing was done by the rewritable laser marker with the character-drawing software automatically removing overlap. Erasure was done by the rewritable laser eraser. Figure 11b shows the results of printing without overlap removal. When overlap is not removed, the intersection and cuff parts remain as a black spot. When overlap is removed, however, uniform erasure is achieved even after 1,000 cycles, demonstrating durability of the medium.



(a) Printing and erasure after overlap removal

(b) Printing and erasure without overlap removal

Figure 11. *Effect of improved repetition durability from overlap removal*

Effects of introduction of rewritable laser system

This technology will enable rewritable recording, thereby helping protect the environment in a variety of fields and increasing business efficiency. In present physical distribution systems, thermal labels are printed and applied to tote containers by auto labelers. The labels must be removed after a single use to allow printing and pasting of new labels, and this creates garbage. In a rewritable laser system that incorporates the new technology, about 1,000 write–erase cycles become possible. Because the lifespan of one label is about the same as the lifespan of a tote container, label waste for the duration of service drops to zero (Figure 12), and CO_2 emissions will also fall by about 90% (Figure 13). This will greatly contribute to reducing environmental impact.

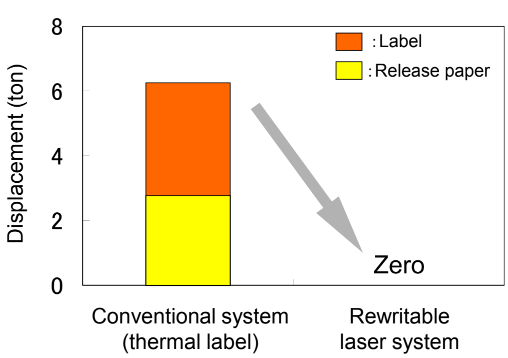


Figure 12. *Amount of discarded-label waste for 5 years from mid-sized physical distribution centers*

We estimate that if this system were used for all physical distribution applications in Japan that currently use tote containers, a yearly reduction of about 4,800 tons of thermal-paper labels would be achieved.

Because conventional thermal labels are peeled off manually, not only must labor expenses must be taken into account but also removal sometimes fails or is incomplete, resulting in the remaining barcode being mistakenly read. This causes problems with sorting and physical distribution. Applying our rewritable laser system reduces labor expenses and does away with problems related to incomplete removal. The result is increased efficiency of logistics operations.

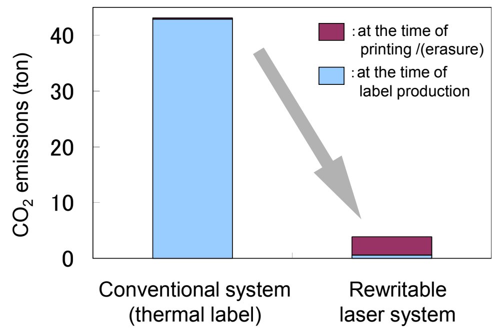


Figure 13. *Amount of CO_2 emissions for 5 years from mid-sized physical distribution center*

Summary

The repetition durability for printing and erasing and the photostability of the rewritable recording medium has been improved by developing a new rewritable laser system. This technology is suitable for deployment within the physical distribution industry.

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Author Biography

Yoshihiko Hotta received his B. Eng. in physics from Nagoya University in 1978 and joined Ricoh Company Ltd. He received his Ph.D. in imaging science from Chiba University in 1997. He has worked in thermal recording and rewritable marking from 1978, focusing recently on rewritable laser marking processes. He is an Executive Specialist at Ricoh Company Ltd., a Fellow of the Imaging Society of Japan (ISJ), and Chairperson of the Electronic Paper Committee in ISJ.