レーザプラズマ式 3D ディスプレイにおけるビルボード表現

Billboard representation for Laser-Plasma Scanning 3D Display

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Abstract: In this paper, we propose a new billboard representation for Laser-Plasma scanning display. The Laser-Plasma 3D display can generate plasma luminous bodies at arbitrary position in midair without any screens. Using this 3D display we can display messages in free space as some kind of billboard that represents sequence of characters formed with dots of plasmas. Dots of plasmas sequentially blink 1000 times a second, by vector scanning. However, there is a restriction on the number of the plasmas which human can perceive simultaneously. In this research, we experiment on the difference of representing characters by changing the density of the plasmas and the drawing way of characters on our system. From some experiment, it can be seen that the way of drawing several times by reducing the density of points is stable to recognize a character, even though the drawing time is the same. Furthermore, the character string is considered, and it can be seen that the way of displaying several characters simultaneously is an appropriate method.

Keywords: Plasma Luminous body，3D Display，Character Representation

1. Introduction

A new device which is able to emit plasma light in midair has been developed for a new 3D display. When a high power laser beam is focused in a gas, ionization of the gas occurs. This phenomenon is called ”laser-induced breakdown” and the ionized gas is ”plasma”. The breakdown of air is accompanied by a bluish white light emission [Michelis 69, Ready 71]. It was known for a long time. Kimura, Shimada, et al. have developed an innovative 3D display device: ”Free Space Display of Point Cloud by Laser-Plasma” that generates 3D images in midair [Kimura 06, Saito 08]. The lights produced by this device are observed as points of light such as the examples in Figure 1.

The device uses 1 kHz pulse laser, and is able to generate plasma luminous bodies 1000 times a second which appear and disappear one by one. The laser beam is controlled by 3D-scanner, and the plasma is generated on the locus of laser. The plasma life span is very short. However, the plasma emits high intensive light, so a plasma luminous body can be seen about 0.2 seconds as an afterimage. Therefore, we can perceive about 200 plasmas simultaneously.

Our 3D display certainly can show 3D dot pattern in midair. However we consider that showing 2D pattern in midair is one of the most significant practical ways of using our 3D display for sending a message to the public viewing. This is why we focus on 2D character pattern in this paper. We also assume that viewers see the display from orthogonal direction to the invisible billboard that is virtually standing in the space.

When a character and its string are displayed in our system, we have to consider the density of the plasma sequence, the display count of a character and the drawing path, so that the viewer can perceive the character and its string. If a character is displayed at the low density of the plasma, it is difficult to recognize it. Moreover, it is also difficult to represent a string of many characters with just 200 dots of plasmas. However, human vision system have the afterimage effect and the iconic memory[Coltheart 80]. We think it is possible to recognize long character string if the display order of characters is considered.

In this research, we examine the difference of human recognition about alphabet when the density of plasma and the display count of a character are changed, and when the display order of a character is changed in character string. On the basis of the result, we propose a method of representation of character string for billboards.

2. 3D Display System

2.1. The drawing mechanism

The structure and the drawing mechanism of the system is shown in figure 2. It consists of an infrared laser generator

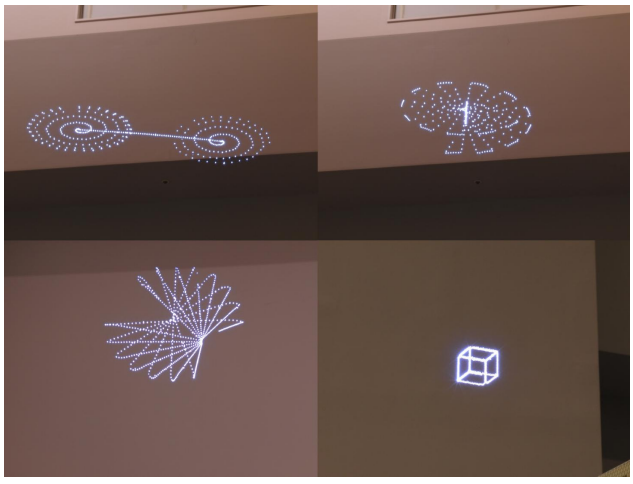


Figure 1: Experiment examples (Shutter speed : 0.5[s], lower left side : 0.8 [s]).

and a 3D-scanner. The laser generator continues to generate one kHz pulse laser, while the 3D-scanner controls the direction of the laser beam and the distance of the focus where the plasma generated.

When the laser is scanning, plasma luminous bodies can be drawn on the locus of laser focus point. The vector scannning is adopted in this system, so the sequential plasma luminous bodies are generated at the arbitrary positions in midair.

2.2. Laser plasma generation

The plasma generation is explained in figure 2. High power infrared laser beam is condensed to one point in midair and energy of atmospheric molecules increases by making oscillation around the focus. Then molecules are ionized it is called plasma. When the plasma is generated, strong light is emitted. The generated plasma returns to original state immediately.

3. Representation of Characters

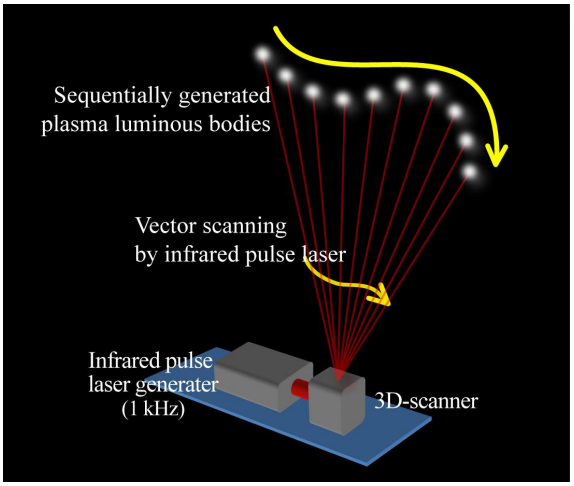


Figure 2: The drawing mechanism. The 3D display device consists of an infrared one kilohertz pulse laser generator and a 3D-scanner. By controlling the scanner, plasmas are generated at the required position.

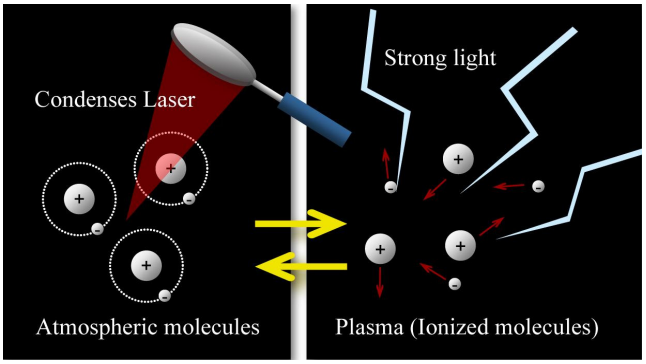


Figure 3: The plasma phenomenon. When high power laser beam is focused in midair, molecules are ionized and strong light is emitted. It is called “plasma”.

3.1. The drawing time and the density

When a character is represented by using point sequence, its visual impression is changed according to the density of point, even if it is the same character. An example is shown in figure 4. If the density of points is too low, it is difficult to recognize a character. Furthermore, when the density of points increases, the time to draw a character once becomes long. That is, the time is in proportion to the density. An example is shown in figure 5; this illustration expresses the simulation for the plasma sequence which is observed in a certain period. The pictures arranged in a column are in the same density, but simulated period is different. In case of the low density, we observe the whole image at each period. However, in case of the higher density, we cannot observe the whole image, so we cannot recognize it stably. What we see is changed not only by the density of points but also as for the time to draw it. Therefore, we have to select appropriately density for characters.

3.2. Representation of a character string

3.2.1. Drawing method

To draw in one stroke, a character string consists of characters connected on the base line of characters. The

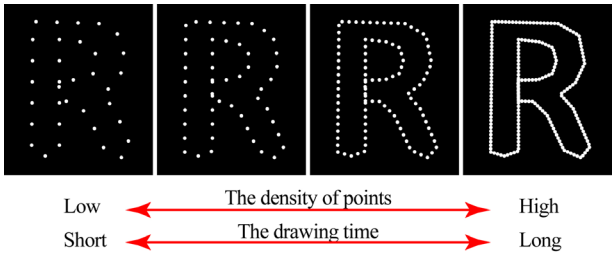


Figure 4: The simulation for the representation of character changing the density of points as to four levels.

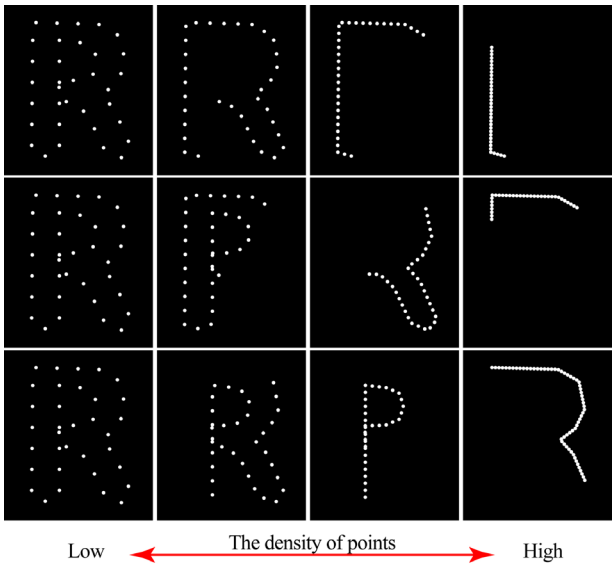


Figure 5: The simulations for a plasma sequence in a certain period. The pictures arranged in a column are in the same density, but simulated period is different.

drawing order of each character is already decided manually. An example of "LASER" is shown in figure 6. The path from the start point to the end point is the basic route. We define this drawing way as the method 1: the straight drawing.

It is impossible to display all the characters of the character string to perceive them simultaneously in our system. If human can see several characters simultaneously in reading sentence, human can understand it. So we consider displaying by a character set to perceive several characters simultaneously. A character set is changed forward of the character string by several characters. An example is shown in figure 7. In the step 1, "LAS" is drawn forward and "SAL" is drawn backward. In the step 2, "LASER" is drawn forward and "RES" is drawn backward. In the step 3, "SER PL" is drawn forward and "LP R" is drawn backward. Some characters are drawn repeatedly. The drawing way is changed by the repeating parameter n_s and the adding parameter n_a. The n_s is the number of characters to draw forward, and the n_a is the number of characters to add at next step. In the figure 7, $n_s=3$, $n_a=2$. We define this drawing way as the method 2: the repeated drawing.

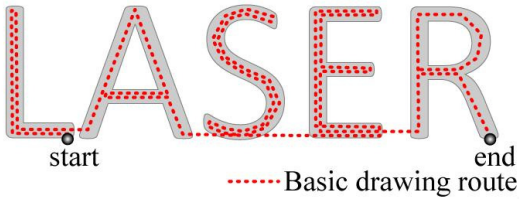


Figure 6: An example of straight drawing (the method 1).

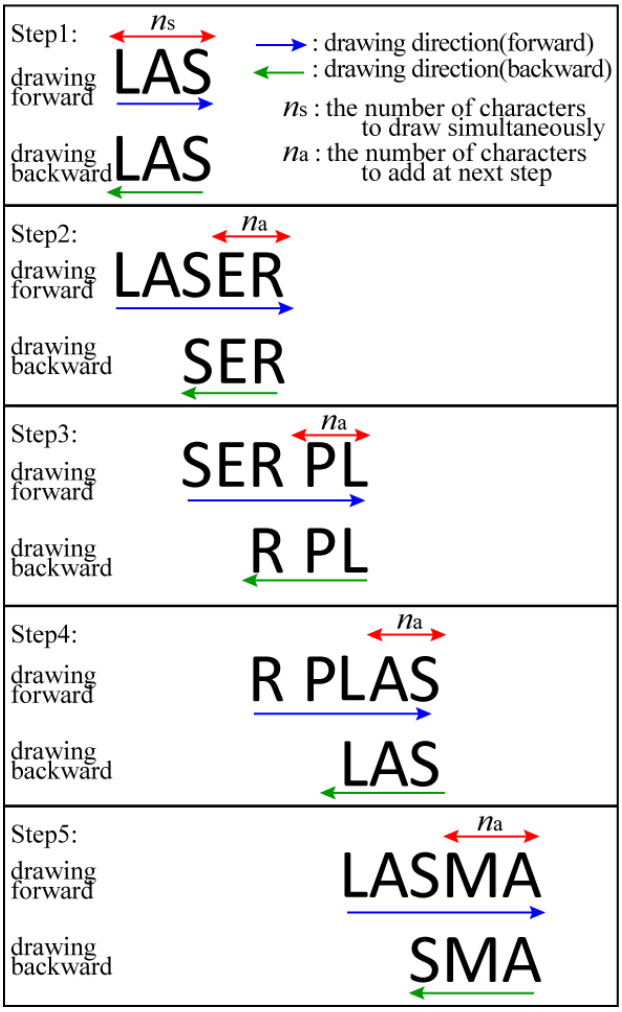


Figure 7: An example of the repeated drawing (the method 2).

3.2.2. Backward drawing method

In our display, objects are drawn by vector scanning; we have to draw in one stroke, so the backward route has to be decided. We adopt two ways to return to the start point. One is the way of straight return to the start point. Another is the way to return through the reverse route from the end point to the start point. Examples of the both way are shown in figure 8. The differences between these ways are the time to draw a character string and the number of drawing a character.

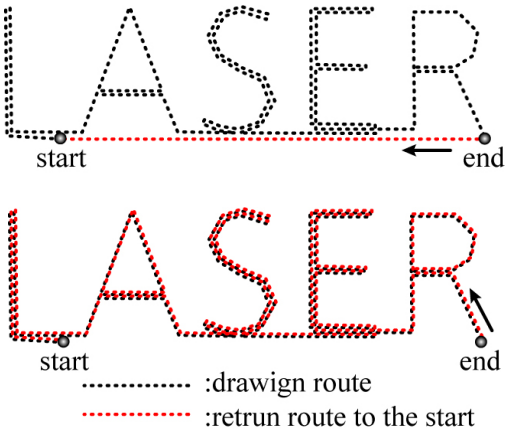


Figure 8: Examples of the return ways to the start point. The upper way is straight route; the lower way is reverse route from the end point to the start point

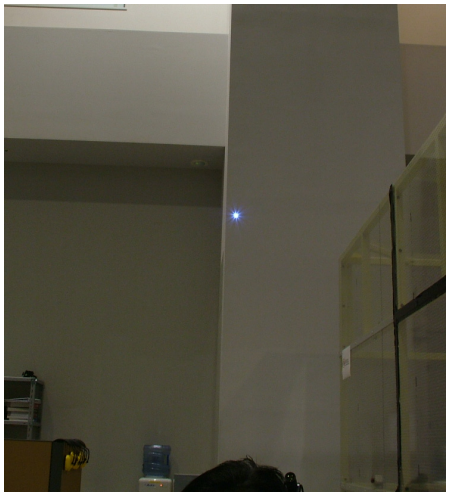


Figure 9: Plasma luminous body. It is a basic state in the 3D display system. (Shutter speed 0.25[s].)

4. Experiments

4.1. The display system

The plasma luminous bodies are generated on the height of about 2 meters in our system. The basic state is shown in figure 9.

4.2. The difference of the density

In the experiment 1, we examine the following parameters in displaying one character.

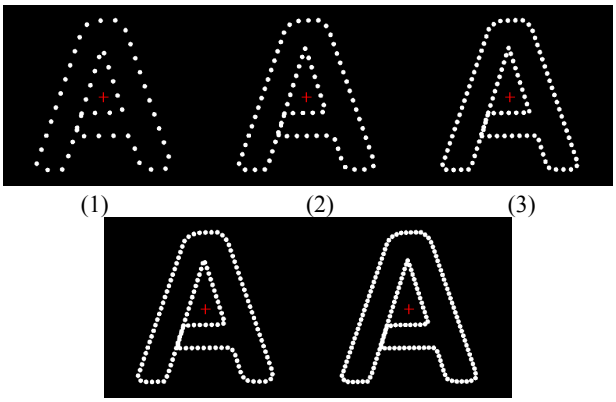
1) The density of plasma sequence.

2) The time to display a character.

The height of displayed character is about 18 cm; the width depends on a character. The simulation as for the density is shown in figure 10. The information of the density, the distance between plasma and the time to drawing a character once is shown in table 1. The examples of the result pictures of "A" are shown in figure 11. The examples of the result pictures of "C" are shown in figure 12. The number under the picture expresses the density number in table 1. The time to drawing a character once depends on the length of its route. Representations of no. 2-4 are perceived stably. The most stable one of five representations is no. 3 in the experiment.

The total time to display a character needs about 240-300[ms]. There is a range in the total time to recognize a character, because the length of drawing route depends on a character. Examples of the displaying scenes as the billboard are shown in figure 13, and in figure 14.

4.3. The representation of character string



(1) (2) (3)

(4) (5)

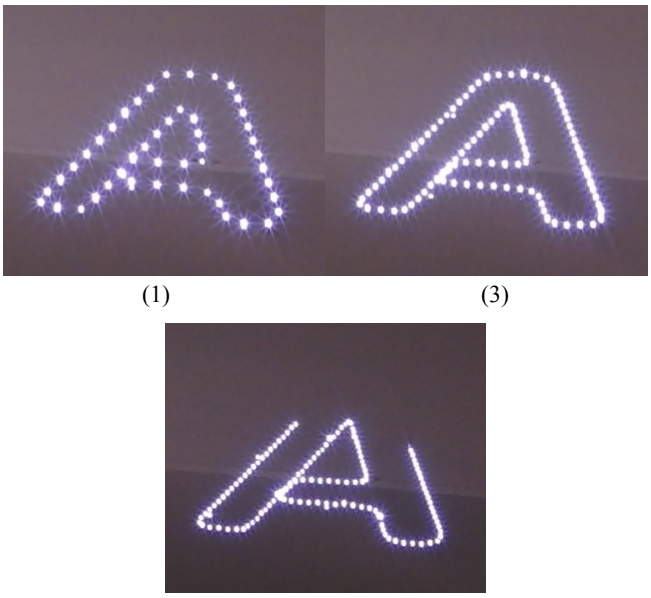
Figure 10: An example of the simulation for the five densities.

Table 1: The five densities in displaying character "A".

No.	The density [points/cm]	The distance[cm]	The drawing time [ms]	
			A	C
1	0.59	1.7	50	40
2	0.90	1.1	75	60
3	1.2	0.85	100	80
4	1.4	0.70	125	100
5	1.8	0.55	150	120

In the experiment 2, we examine the methods of representing character string which are defined in 3.2. There are four kind way with combination of the drawing method and the backward drawing method. The number of the combination method is shown in table 2. Here we adopt the repeating parameter n_s=3 and 5, the adding parameter n_a=1. Examples of displaying character strings are shown in figure 15, in figure 16. The height of characters is about 5 cm, and the density of plasma is 1.1 [points/mm]. The width of a short character string example "PLASMA" is about 22 cm, and the width of a long character string example "LASER PLASMA" is about 40 cm.

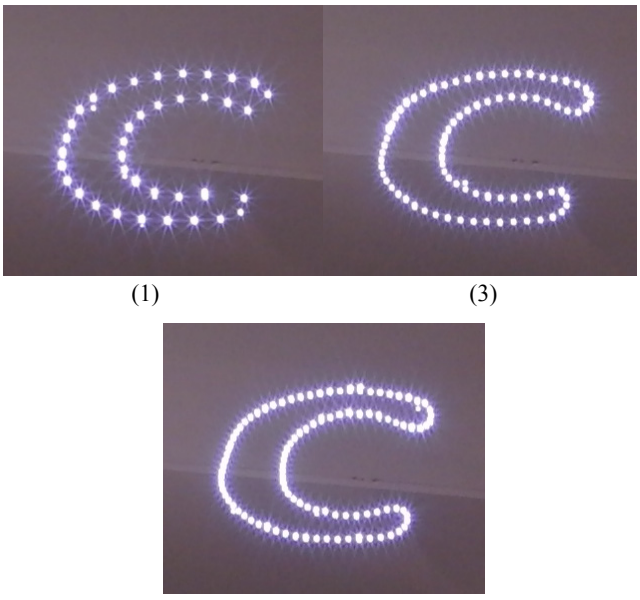
In figure 15, an example of "PLASMA" with the straight drawing and route return method (1-2 in table 2) is shown.



(1) (3)

(5)

Figure 11: The result of "A". The number is the density number (Shutter speed: (1), (3) 0.20[s], (5) 0.125[s].)



(1) (3)

(4)

Figure 12: The result of "C". The number is the density number (Shutter speed: 0.20[s].)

In figure 16, an example of “LASER PLASMA” with the straight drawing and straight return method (1-1) is shown. We cannot express the repeated drawing method, however, in figure 17, an example of a part of “LASER” with the repeated drawing and straight return method (2-1) is shown.

Figure 13: The “A” on the billboard. We can see a floating “A” in midair. (Shutter speed: 0.20[s].)

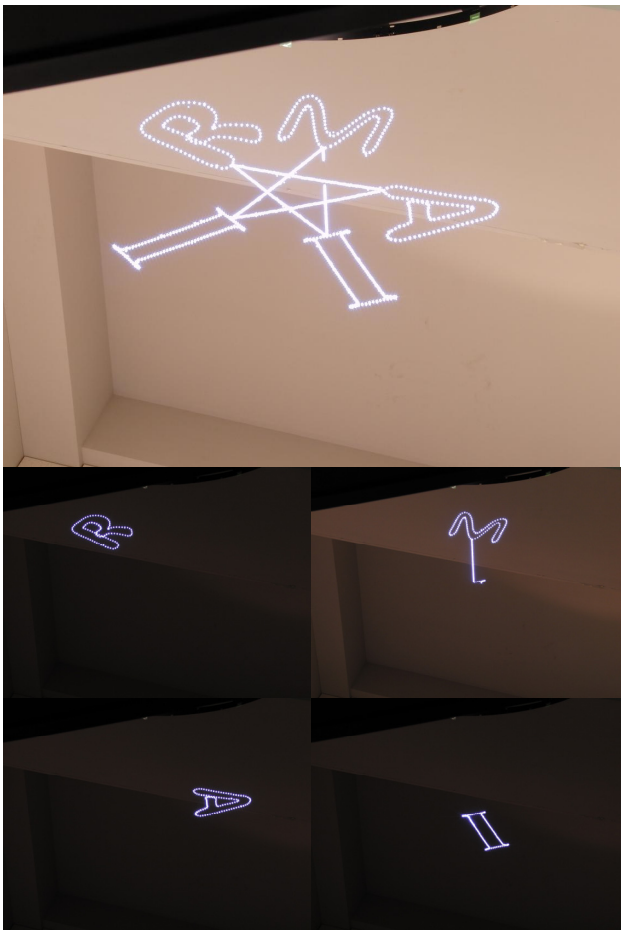


Figure 14: An example of the designed alphabet. The upper picture was taken by shutter speed 1.6 [s]. So, all the character appears in this photograph; actually we cannot see all the characters simultaneously, such as the lower pictures. The lower pictures (A, R and I) were taken by shutter speed 0.125 [s], and M was taken by shutter speed 0.33[s].

The repeated area is brighter than single drawing. However, the impressions from the real display differ from photographs unfortunately.

In case of a short character string, such as “PLASMA”, we can recognize it with all methods in table 2. In case of a long character string, such as “LASER PLASMA”, we cannot recognize it with 1-1 and 1-2. However, we can recognize it with 2-1 and 2-2.

There is the difference in recognizing a character string according to the n_s at a long character string. In both case, n_s=3 and 5, we can recognize a character string. However, we can recognize it with n_s=5 easily than with n_s=3.

4.4. Discussion

As for the density of plasma sequence, we found that the density of about 1.1 [point/cm] is appropriate. In case of the lower density, it is difficult to recognize a character, on the other hand, in case of the higher density, a character is not stable because of flicker. As for the total time to display a character, we found that about 240-300[ms] is appropriate for complete understanding of a character. The time to recognize a character is longer than the time of afterimage

Figure 15: The result of “PLASMA” with the straight drawing and route return method. (Shutter speed: 0.25[s].)

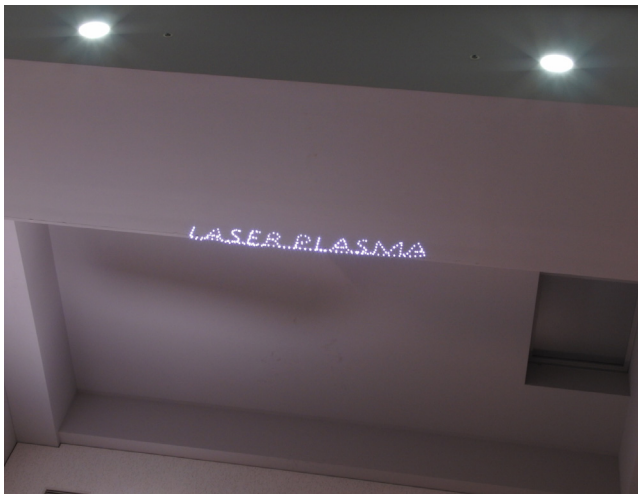


Figure 16: The result of “LASER PLASMA” with the straigh drawing and straight return method. (Shutter speed: 0.25[s].)

Table 2: The combination method

No.	The drawing method	The backward drawing method
1-1	Straight drawing	Straight return
1-2	Straight drawing	Route return
2-1	Repeated drawing	Straight return
2-2	Repeated drawing	Route return

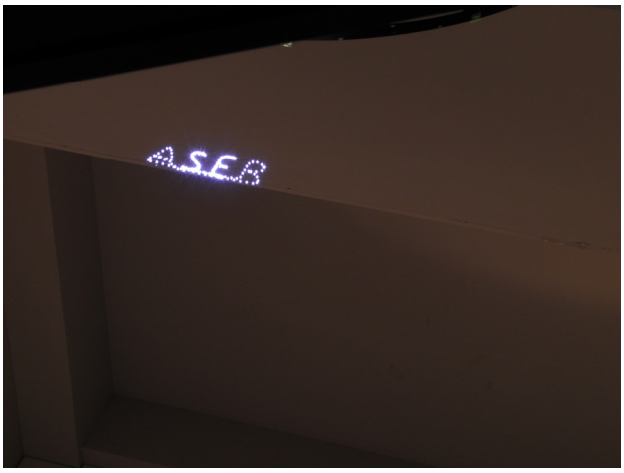


Figure 17: An example of a part of "LASER PLASMA" with the repeated drawing method. The repeated area is brighter than single drawing. (Shutter speed: 0.25[s].)

generated by the plasma. Therefore, drawing of a character should be repeated several times for stable perception.

As for the method of drawing a character string, the both methods we proposed are good for short character strings. However, the method of straight drawing is not available for long character strings. We have to display by five characters for a long character string.

We examined the two ways of the backward drawing, unfortunately, there was no relation to recognizing character strings in these experiments. However the backward drawing is very effective as for attractive representations of character string, such as neon sign billboards.

5. Conclusions

In this paper, we proposed a method of representing characters as a billboard for the laser plasma scanning 3D display. The density of plasma sequence and the repeat number of displaying a character were examined as for representing a character. From the experiments, it was found that the best density is about 1.0 [point/cm] in the current system, and that a character has to be drawn about three times to perceive it. By using this density and the repeating count, we can perceive characters stably on our display. However, it is difficult to recognize a simple form character, for example "I", from its form. In case of such an ambiguous form, the character has to be displayed as character string which we can know it. As for the representing character string, it was found that we can perceive a character string stably by using a method of drawing several characters repeatedly.

In future works, we have to consider not only displaying characters, but also representing a longer sentence for an effective communication, such as moving characters.

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