Laser Signal Projection for Effective Lane Change on Expressway

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ABSTRACT

For the purpose of reducing the traffic accidents at the construction zone of the expressway, "guiding arrows" on the road are realized by the laser signal projectors. The ratio of incoming vehicles was decreased from 13.9 % to 0.9 % by the combination with internally illuminated warning signs.

1. INTRODUCTION

There have been almost 8000 of traffic regulation at Hanshin Expressway (Japan, Fig. 1), while several injury accidents caused by the incoming vehicles have been occurred within almost 100 of total accidents. Although there are safety measures such as safety cones, warning signs, lamps etc. around the construction zone to prevent such accidents, effective safety measures for "pre-caution" are expected to decrease the number of incoming vehicles toward construction zone.

Fig.1. Hanshin Expressway (Osaka, Japan)

For this purpose, there are "passive" warning signs on the shoulder of the road, which have been started several hundred meters away from the zone. However, they do not have enough impact at night compared to daytime. One reason is that the headlight of the car cannot cover whole range of driver's view with sufficient illuminance, i.e. especially it is hard to enhance the object at far field. The other reason is that it is difficult to recognize the warning signs outside of the lane, because of the shrinkage of the peripheral vision of the driver with the velocity [1] in the expressway.

DNP has been developed laser signal projector for road applications. It was firstly revealed in 2019 [2], and the prototype has been announced in 2022 [3] as in Fig. 2.

Fig.2. Prototype of laser signal projector.

Internal battery enables stand-alone operation for 3 hours in lighting mode, and 6 hours in flickering mode. With using small mobile batteries (e.g. for smart phone), whole night operation can be available. Regarding the laser-eye-safety, the laser signal projector is "class1 laser product" according to IEC 60825-1:2014, and RG2 (Risk Group 2) as per IEC 62471:2006 for the use in Japan. The key-feature of the laser signal projector is that it can cover near-to-far field and provide enhanced visibility for the driver in terms of image resolution and uniformity.

2. CONCEPT

2.1. Guiding arrow by laser signal projector

The situation of accidents caused by incoming vehicles is illustrated in Fig. 3. As explained in the section 1, the drivers who get close to the construction zone would miss the warning signs which appear repeatedly at the shoulder of the road because of the
narrower viewing area, while most of other drivers change their lanes in advance to avoid crash at the “tapered part” of the safety cones.

Fig. 3. Schematic of the accident by incoming vehicle.

The approach of this study is to display “guiding arrow” on the road by the laser signal projector from the side wall or the shoulder of the road. The guiding arrow was designed to be found from far field, e.g. over 50 m away. The example of photo taken from 20 m away from the guiding arrow is shown in Fig. 4. Excellent positive contrast has been achieved under the road lighting of the expressway.

Fig. 4. Photo of guiding arrow taken from 20 m away at the restricted area on Hanshin Expressway.

The assumed use-case is that the guiding arrows are displayed far away from the construction zone for the earlier lane change. Only the guiding arrow may not be enough for the driver to tell the message correctly. Therefore, the laser signal projector is installed at the lower or upper side of an internally illuminated warning sign as shown in Fig. 5.

Fig. 5. Laser signal projector with internally illuminated warning sign.

Internally illuminated warning sign equipped retroreflection sheet at the front which transmitted a part of backlight.

2.2. Operation on the expressway

Operating configurations is shown in Fig. 6. Several sets of laser signal projectors and internally illuminated warning signs were placed between the section of 500 m and 200 m before the tapered part of the safety cones to encourage the earlier lane change for the drivers.

Fig. 6. Operating configuration on the expressway.

Laser signal projectors were operated as continuous lighting mode, while internally illuminated warning sign are in the flickering mode.

3. VALIDATION

3.1. Method

To estimate the impact of guiding arrow with internally illuminated warning sign, experiments have conducted at Hanshin Expressway (Osaka) through July to August 2022. The experimental configurations are shown in Fig. 7.
The camera had been set on the top of the large safety cone to count the total number of vehicles passed through, and the number of vehicles which was approaching just in front of the tapered part of the construction zone. The number of the guiding arrows were changed from zero to seven. The ratio of the approaching vehicles to the total vehicles was used as a parameter of effectiveness. When the number of guiding arrows was zero, retroreflective (passive) warning sign was set instead, which was widely used in general.

3.2. Results

It was difficult to take the photo of whole picture of this experimental setup on the actual expressway, because it was so dangerous to remain on the expressway to take photos or other activities other than setup operation. Instead, Fig. 8 shows the one in the test course located under the expressway. The guiding arrows could be recognized as an “arrow” over 50 m away, and the existence of the arrows and the warning signs could be found over 100 m away.

The photo in Fig. 9 was actually taken by the dashboard camera of test vehicle on the expressway. Even if the guiding arrow was overlapped with both road lighting and headlight of the car, it still kept enough positive contrast.

The statistics of approaching vehicles toward tapered part of the construction zone is shown in Fig. 10. It is remarkable that 13.9 % of so many vehicles were approaching just in front of the construction zone in case of default condition (retroreflective warning sign only). However, more interesting fact is that the ratio was dramatically dropped below 1 % when the number of the guiding arrows was over three.

According to the impact of effectiveness of these experiments, actual operation of the laser signal projector with the internally illuminated warning sign was officially permitted in Osaka region of Hanshin Expressway. The operation has been started since December 2022.
4. CONCLUSIONS
For the purpose of reducing the traffic accidents at the construction zone of the expressway, "guiding arrows" on the road are realized by the laser signal projectors. The ratio of incoming vehicles was decreased from 13.9 % to 0.9 % by the combination with internally illuminated warning sign.

REFERENCES